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Plan and Concepts for Multi-Use Management of the Atchafalaya Basin

Coastal Environments, Inc, Baton Rouge, La

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The report determines surface water requirements of the natural resource complex, including fishes, wildlife, and forests, and the socio-economic resource uses, including flood control, urban and industrial development, mineral extraction, transportation, agriculture, and recreation. Requirements are expressed in terms of desirable annual water-level variation, and resulting hydrographs are compared with those for present and proposed conditions associated with channelization. Minimum volumetric inflow requirements were calculated on the basis of storage characteristics and water levels as attained at present. Hydraulic geometry of the present main river channel is analyzed, and those channel dimensions that are in equilibrium with bankfull discharge suggest that channel enlargement through dredging should not go beyond a cross-sectional area of 7,400 square meters.

A surface-water management plan is presented that is believed to provide for maximum longevity of the remaining swamp ecosystem, to minimize the conflict arising from flood-control needs, and to make possible compatible derivation of benefits from both renewable and non-renewable resources.

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Runoff	*Hydrography	Wetlands	08 A, F, H
Water quality	Deltas	Water management	13 B
*Flood control	Swamps	Channel stabilization	
Sedimentation		Crawfish	
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by

Johannes L. van Beek
William G. Smith
James W. Smith
Philip Light

Coastal Environments Inc.
1260 Main Street
Baton Rouge, Louisiana 70802

Contract No. 68-01-2299

Project Officers

Harold V. Kibby
(Project Officer through August 1975)
Corvallis Environmental Research Laboratory
Corvallis, Oregon 97330

Victor W. Lambou
(Project Officer from September 1975 to Present)
Environmental Monitoring and Support Laboratory
Las Vegas, Nevada 89114

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL MONITORING AND SUPPORT LABORATORY
LAS VEGAS, NEVADA 89114

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FOREWORD

Protection of the environment requires effective regulatory actions which are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach which transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound integrated monitoring data based through multidisciplinary, multimedia programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment
- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report presents plans and concepts for multi-use management of the Atchafalaya Basin surface waters. The U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the U.S. Department of the Interior, the State of Louisiana, special interest groups, and other interested individuals will use this information to assess the potential impact of a massive channelization project proposed by the Corps and to develop alternative land and management plans, which will accommodate flood-flows and maintain an acceptable level of environmental quality. For further information contact the Water and Land Quality Branch, Monitoring Operations Division.

George B. Morgan
Director
Environmental Monitoring and Support Laboratory
Las Vegas

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LIST OF ABBREVIATIONS

cfs	cubic feet per second
cm	centimeter(s)
cms	cubic meters per second
EPA	U.S. Environmental Protection Agency
ft	feet
ft^2	square feet
fwy	floodway
GIWW	Gulf Intracoastal Waterway
g/l	grams per liter
in	inch(es)
kg	kilograms
km^2	square kilometers
lb	pounds
m	meters
μ	micron(s)
m^2	square meter(s)
m^3	cubic meter(s)
mg	milligrams
mg/l	milligrams per liter
mi^2	square miles
ml	milliliters
mm^2	square millimeters
mos, mths	months
MSL	mean sea level
N	nitrogen
NSTL	National Space Technology Laboratories
P	phosphorus
ppm	parts per million
USCE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior
yd^3	cubic yards

CONVERSION FACTORS

Symbol	When you know	Multiply by	To find	Symbol
μ	microns	0.00003937	inches	in
mm	millimeters	0.0393701	inches	in
m	meters	3.28084	feet	ft
m	meters	1.09361	yards	yd
km	kilometer	0.621371	miles	mi
ha	hectares	2.47105	acres	acre
m^2	square meters	10.76	square feet	ft^2
m^2	square meters	1.19599	square yards	yd^2
km^2	square kilometer	0.3861	square miles	mi^2
m^3	cubic meters	35.31	cubic feet	ft^3
ml	milliliter	0.033810	ounces	oz
l	liter	1.05669	quarts	qt
mg	milligrams	0.00003527	ounces	oz
g	grams	0.03527	ounces	oz
kg	kilograms	2.20462	pounds	lb

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SUMMARY

This study centers on conflicts between human use and environmental quality of the Atchafalaya Basin, Louisiana, as related to surface waters. Most eminent in the Atchafalaya Basin are the biological resources constituted by its bottomland and swamp environments. Existence and long-term use of these resources are increasingly endangered as a result of human action related to use of the area's land and waters for flood control, urban and industrial development, navigation, agriculture, and mineral extraction. In addition, cultural uses also have become mutually incompatible. Further rapid deterioration of environmental quality must be anticipated if necessary authorized flood control measures, in particular stream channelization, are not brought in agreement as much as possible with natural resource and cultural values and if no measures are taken to achieve a distribution of present and future uses that takes into account the constraints placed by the natural setting.

Mutual conflicts between the various uses present in the Atchafalaya Basin have a common denominator in that they largely arise from incompatible requirements with regard to surface water management. A study was, therefore, undertaken to develop a plan for management of surface water that allows, as much as possible, compatible use of the basin's many resources. Following initial research, which focused on identification of the basin's environments and the manner in which their aggregate characteristics are controlled and affected by natural processes and various human uses,[1] the present report's starting point is the determination of surface water requirements of the natural resource complex, including fishes, wildlife, and forests, and the socioeconomic resource uses, including flood control, urban and industrial development, mineral extraction, transportation, agriculture, and recreation.

The most general requirements are 1) reduction of sedimentation to preserve floodway capacity and aquatic habitats, 2) improvement of water quality, 3) provision of flood protection for existing development in the Morgan City - Lake Verret area, 4) reduced flooding of the Terrebonne marshes, 5) separation of deep water access to Morgan City from the developing Atchafalaya Delta, 6) management of surface water runoff from developed natural levee ridges surrounding the swamp environment, 7) limitation of expansion of exploitative uses from the natural levee ridges into marginal swamps, and 8) integration into rather than superposition on the swamp environment of mineral industry canals. For the Atchafalaya Basin Floodway, requirements

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[1] Coastal Environments, Inc., Environmental Base and Management Study: Atchafalaya Basin, Louisiana (Through Center for Wetland Resources, Louisiana State University for the U. S. Environmental Protection Agency, 1974a), 228 p.

are expressed in terms of desirable annual water level variation, and resulting hydrographs are compared with those for present and proposed conditions associated with channelization. Furthermore, simultaneous consideration of topography and hydrographs allowed determination of areas experiencing specific hydroperiods under the above three conditions, present, proposed and managed, with hydroperiods related to swamp habitats. Additionally, water availability from rainfall was calculated on a monthly basis in order to determine the extent to which river water could be substituted by local runoff so as to reduce the influx of fluvial sediment. Minimum volumetric inflow requirements were calculated on the basis of storage characteristics and water levels as attained at present.

Hydraulic geometry of the present main river channel is analysed, and those channel dimensions that are in equilibrium with bankfull discharge are determined. Assuming this discharge to be the controlling factor in further natural channel development, the most probable natural stream profile is calculated, and associated channel dimensions are compared with proposed dimensions following channelization. The analysis suggests that channel enlargement through dredging should not go beyond a cross-sectional area of 7,400 square meters* (m^2) or 80,000 square feet (ft^2) as expressed below project floodflow line. Exceedence of this dimension is likely to lead to voluminous dredging and spoil disposal requirements unless the channel is confined by artificial levees.

On the basis of general water management requirements for the Atchafalaya Basin as a whole and specific requirements for the floodway swamps, a multi-use management plan is developed. First, management zones are defined, with each incorporating as many possible existing land uses that are compatible with the primary management objectives. Management zones are grouped into categories of protective use, which includes mostly the forest and aquatic habitats, exploitative use (where substantial development has already occurred) and a buffer zone whose function is to minimize conflicts between exploitative and protective uses. Strategies for management of each of the above zones are set forth. Having defined a compatible distribution of land uses, a surface water management plan is presented that is believed to provide for maximum longevity of the remaining swamp ecosystem, to minimize the conflict arising from flood control needs, and to make possible compatible derivation of benefits from both renewable and non-renewable resources.

* See Appendix for conversion to metric measure.

1
INTRODUCTION

Regional Setting

The Atchafalaya Basin is an 1,800-square mile lowland between natural levee ridges of present and former Mississippi River courses in southcentral Louisiana (Figure 2-1). The natural basin extends northward for some 120 miles from the Gulf of Mexico between the levee ridges of Bayous Cypremort and Teche to the west and Bayou du Large, Bayou Lafourche, and the Mississippi River to the east. Central to the basin is the Atchafalaya River, which carries the combined flow of the Red River and part of the Mississippi River into Atchafalaya Bay. The basin is naturally divided by the east-west oriented levee ridge of Bayou Teche at the latitude of Morgan City. To the south of this ridge, the basin has an estuarine character dominated by fresh to brackish marshes and water bodies. To the north, freshwater environments dominate, ranging from swamp forest to bottomland hardwoods, depending on topography and related hydroperiods.

Of major consequence with regard to natural setting is the use of the Atchafalaya Basin in flood control of the lower Mississippi Valley. Paralleling the Atchafalaya River at an average distance of 8 miles from the river, guide levees extend southward from the Mississippi River near Simmesport to the Teche ridge. These levees and the intermediate area constitute the Atchafalaya Basin Floodway. Control structures at the Mississippi River allow for diversion of Mississippi River water into the floodway as a relief measure. Water is then guided through the basin into the Lower Atchafalaya River at Morgan City and into an additional manmade channel, the Wax Lake Outlet, both of which discharge into Atchafalaya Bay.

The floodway guide levees effectively segment the natural basin north of the Teche ridge in a central area adjacent to the Atchafalaya River, and an eastern and western area (contained between the guide levees and the basin's natural boundaries), the Verret and Fausse Point Basins, respectively (Figure 2-1). As a result, the central floodway area is largely dominated by riverine forms and processes and subject to annual overflow, whereas input of water and materials and water level changes in the adjacent sub-basins are predominantly a function of local runoff.

The Atchafalaya Basin has experienced much environmental change.[2] Initial changes were related to increasing natural diversion of Mississippi River water and sediment into the Atchafalaya River and an associated intensification of riverine processes throughout the

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[2] Ibid.

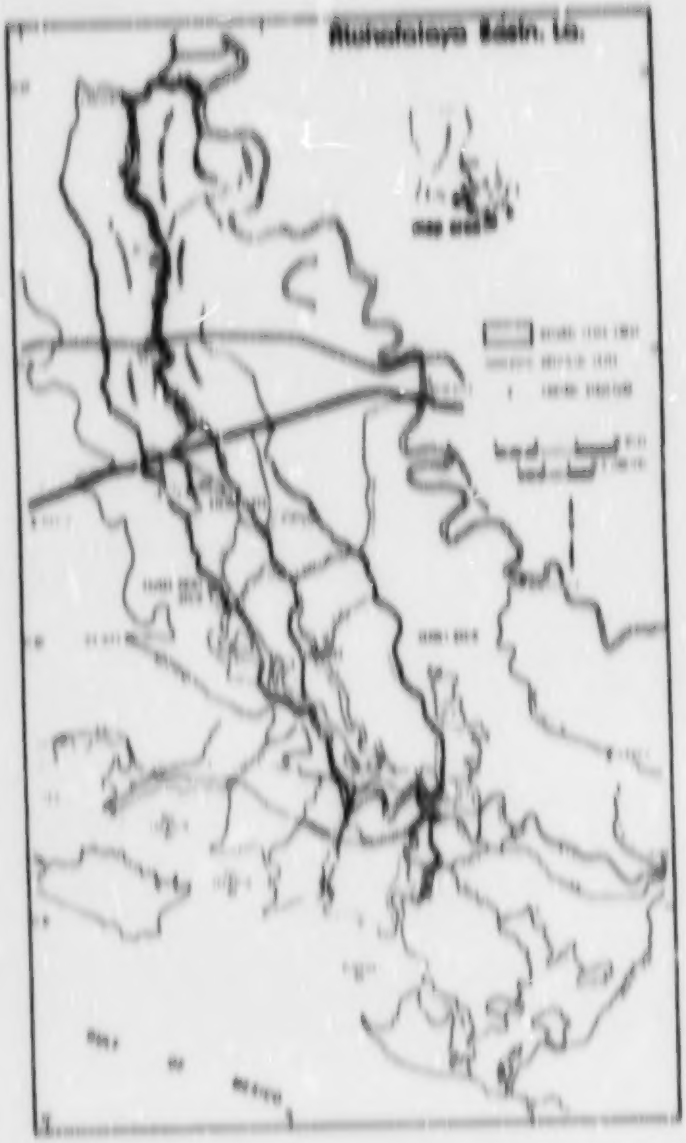
Atchafalaya Basin, La.
GULF
OF
MEXICO

Figure 2-1. Atchafalaya Basin in southcentral Louisiana as confined by Bayous Teche and Cypremort to the west and by the Mississippi River, Bayou Lafourche, and Bayou du Large to the east.

basin. Through lacustrine delta building, many of the extensive lakes formerly existing along the axis of the basin were gradually filled and replaced by swamp forest communities. The river became engaged in building a floodplain with a well-defined, natural-levee-bounded channel and backwater areas in which remaining lakes would be bypassed by sedimentation and new lakes would form as a result of natural ponding. However, before such an environment could be fully realized, natural processes and trends were modified greatly. Water levels became subject to greater fluctuation as flows were confined to the central part of the natural basin through construction of floodway levees. Channelization of the Main Channel and four major distributaries, together with associated spoil deposition, forced change in the water distribution mode from overbank flow to channel flow. These combined interventions redirected sedimentation from the natural levees to backwater areas, thus reducing the trend toward natural topographic and habitat diversity. At the same time, they accelerated the rate of southward channel development so that increasing volumes of sediment are now carried into Atchafalaya Bay, where a marine delta is presently emerging. Within the central part of the Atchafalaya Basin, change from a natural to an artificial floodway has set in motion a trend from natural and diversified floodplain development toward a more uniform terrestrial habitat.

In contrast to the floodway segment, change of the Verret and Fausse Point Basins has been greatly retarded as a result of severance from riverine processes. Large water bodies such as Lake Verret, Lake Palourde, and Lake Fausse Point have been retained, as have the extensive swamp forests.

Statement of Regional Problem

Against the above setting, the regional problem underlying the present study can be discussed. This problem centers on human use of the area's resources and quality of its environment as they relate to surface water. Inherent to the geologic and general natural setting, the Atchafalaya Basin is extremely rich in both renewable and nonrenewable resources. Most eminent are the biological resources. The bottomland hardwoods, swamp forests, and associated water bodies provide habitats for greatly varied and extensive populations of wildlife, including endangered species and fishes.[3] Together these elements constitute a renewable resource of food, raw materials, and recreation that, considering its magnitude, is of national importance. In addition, the Atchafalaya Basin's primary production is likely to contribute substantially to marine fisheries through export of detrital matter from the basin to adjacent waters of the Gulf of Mexico.

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[3] U.S. Department of the Interior, *A Progress Report: Fish, Wildlife, and Related Resources, Atchafalaya River Basin, Louisiana* (1974), 195 p.

The above complex of resources has evolved and is maintained predominantly through natural processes. In that regard, they contrast with a second complex of the basin's resources, use of which has necessitated man's interference with the natural environment. This second complex includes the (artificially or naturally) better-drained lands along the margins of the basin used for agricultural, industrial, urban, and transportation development, the natural waterways which have been modified for navigation and flood control, the space used for flood control, and the oil and gas deposits which invoked extensive canal dredging for transport and extraction.

Summarized from the above point of view, one may consider two resource complexes, the first of which may be referred to as natural resources, the second as socio-economic resources in the sense that use in the present form is brought about by and relies predominantly on socio-economic pressures and demands. As a result of the natural setting of the area, requirements for maintenance and use of resources in both complexes relate in the first instance to surface-water aspects; these include quality, quantity, depth, seasonal and areal distribution, and water level. Required surface-water conditions differ greatly, however, between the two resource complexes, and to some extent within a complex. These differences tend to be magnified when, out of choice or necessity, the resource uses of the two complexes become geographically intertwined in a pattern that disregards contraints placed by the natural or socio-economic environments. This is precisely what has happened in the Atchafalaya Basin, resulting in the present regional problems and urgent need for management of surface water and land use.

Within the middle floodway north of Morgan City, surface-water problems stem from the conflict between the annual overbank flooding and dewatering regime as required for fish, wildlife, forest, and recreational purposes,[4] and the channelization, canal dredging, and depositing of spoil. The latter actions, as associated with flood control, navigation, and mineral extraction, have favored channel flow at the expense of overbank flow, increasing siltation in lakes and backswamps and interrupting backwater circulation with adverse effects on water quality.

In the upper floodway north of U. S. Highway 190, Atchafalaya River levees have diminished flood frequency, allowing agricultural development within the floodway with concomitant requirements for better drainage and reduced diversion of Mississippi River water through the Atchafalaya Basin. This poses a dual conflict, namely between water requirements of the middle and upper floodway and requirements for agricultural and flood control use of land within the upper floodway.

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[4] Coastal Environments, Inc., 1974a, *op. cit.*

Containment of flood flows within the floodway-guide levees has reduced flood threats to the Verret and Fausse Point Basins, allowing expansion of agricultural development from the bounding natural levees into adjacent wetlands. This has magnified the conflict between drainage requirements for agriculture and its associated runoff and requirements for annual water-level fluctuations and high-water quality of the swamp ecosystem within these basins.

In the estuarine and deltaic part of the Atchafalaya Basin south of the Teche ridge, requirements for resource use and maintenance are equally conflicting under present conditions. In various ways, flood control, mineral extraction, and navigation channels have allowed uncontrolled diversion of fresh water into the marshes and bays to the east of Atchafalaya Bay, producing extensive and prolonged flooding with resultant marsh deterioration and adverse effects on productive oyster grounds. A second conflict rapidly increases in magnitude with accelerated growth of the Atchafalaya Delta. In view of rapid deterioration of Louisiana's coastal environment, delta building is a highly desirable process as a means of restoring renewable resources lost in adjacent areas. Sediment is deposited, however, at the mouth of the same channel required for deep-water access to industries in the Morgan City area. Increased efficiency of the Atchafalaya River within the floodway as required for flood control can only contribute to accelerated sedimentation. Additionally, delta-progradation toward the Gulf of Mexico will displace the river mouth seaward, thus progressively increasing mean river-stages in the vicinity of Morgan City.

Objectives and Relationship to Other Studies

The conflicts of land use and surface water requirements, as discussed summarily in the preceding paragraphs, and the associated deterioration of environmental quality and related natural resource base point out the necessity for management of resource use in the Atchafalaya Basin. This need has gained considerable urgency with pending plans for further channelization of the Atchafalaya River to increase floodflow efficiency and of Bayous Chene, Boeuf, and Black to improve navigational access to fabrication yards of offshore drilling platforms. To deal with the eminent regional problems, the U. S. Congress in September, 1972, resolved that a land and water management study of the Atchafalaya Basin be undertaken jointly by the Army Corps of Engineers, the Department of the Interior, and the U.S. Environmental Protection Agency. Central to this study is the objective to develop a multi-use land and water management plan that allows compatible use of the basin's resources. At the same time, knowledge gained through the land and water management study is to aid in the evaluation of possible adverse environmental effects that may be caused by further actions necessary to complete the Atchafalaya Basin Floodway Project as authorized by Congress in 1928. In particular, the effect of additional channelization of the Atchafalaya River and resultant modification of the annual overflow regime are envisioned as having possible major consequences with regard to fish, wildlife, and recreational resources.

Within the above framework, a number of closely related studies have been undertaken of which the present study dealing more specifically with surface-water aspects of the Atchafalaya Basin is an integral part. Initiated by the Environmental Protection Agency in 1973, the study has had as its primary objective the development of a surface-water management plan that allows compatible use of the basin's multiple resources. Inherent to the nature and relative magnitude of the problems, work has focused in particular on the designated use of the central area as a floodway and associated modification of the overflow regime versus the need to sustain the overflow swamps as one of the basin's principal assets in regard to long-term benefits.

As a prerequisite to development of a surface-water management plan, it is imperative that surface-water requirements are defined for all major elements of the Atchafalaya Basin resources complex. Furthermore, it is necessary to understand the manner in which the basin functions as a natural system and to identify trends and their relationship to both man-induced and natural processes. In this regard and as an aide to evaluation of proposed flood control features, development of an environmental base has been an equally important objective of the study.

Concurrent with the present effort and also within the framework of the Atchafalaya Basin Land and Water Management Study, additional investigations have been undertaken by the Environmental Protection Agency, the Department of the Interior,[5,6] and the Army Corps of Engineers. Department of the Interior studies have been directed largely toward development of a biological data base, with emphasis on fish and wildlife resources and their respective habitats in the floodway and Atchafalaya Bay. Resulting baseline data have been fully utilized in the present study in determination of management requirements. Directed more specifically toward development of a surface-water quality base and identification of annual variation and long-term trends is an ongoing sampling program by the Environmental Protection Agency. In addition, a land-use suitability study for the entire natural basin has been undertaken by the Army Corps of Engineers.

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[5] U. S. Department of the Interior, 1974, *op. cit.*

[6] C. F. Bryan et al., *Annual Report: A Limnological Survey of the Atchafalaya Basin* (Louisiana Cooperative Fishery Unit, Louisiana State University, 1974), 208 p.

Of further benefit to the development of a land and water management plan for the Atchafalaya Basin has been the involvement of state agencies, particularly the Atchafalaya Basin Division of the Department of Public Works and the Louisiana Wild Life and Fisheries Commission. Building further on the approaches and data developed through the above-mentioned research efforts, a special study[7] was undertaken through the Atchafalaya Basin Division to develop a detailed management plan for the Buffalo Cove Swamp located within the Atchafalaya Floodway. Development of this plan has, in turn, furthered definition of management requirements for the overflow swamp environment and understanding of the present resource-use conflicts. A number of biological studies are presently funded by the Louisiana Wild Life and Fisheries Commission.

Approach

Within the Atchafalaya Basin, natural processes and human action have combined to produce an environmental differentiation, characterization of which has been the basis for both plan development and impact analysis. The first phase of the water management study, undertaken during 1973, focused largely on identification of the basin's environments and the manner in which their aggregate characteristics are controlled and affected by natural processes and various human uses. Based on an analysis of process-environment relationships, the natural basin was considered in terms of four environmental complexes: channel, natural levee, flood basin, and marine deltaic. Each complex is made up of a characteristic assemblage of natural elements, but with cultural elements superimposed. Thus, for example, within a floodplain complex one may identify such natural elements as swamp, natural levees, abandoned channels, and lacustrine delta, each of which also represents a definable habitat. Added to these, often without regard to natural boundaries, may be manmade elements such as canals or a highway. Environments, then, were viewed as the products of specific processes which determine their mutual spatial relationship and present characteristics as well as their rate and direction of change. This allowed division of each complex into management units within which environmental conditions as related to natural processes and human use, and therefore management requirements, were similar (Figures 2-2 and 2-3).

Within swamp management units, water levels and surface elevation are the primary controls of biological habitat and suitability for

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[7] Coastal Environments, Inc. Water Management Plan, Buffalo Cove Swamp (Developed for the Atchafalaya Basin Division, Department of Public Works of the State of Louisiana by Coastal Environments, Inc., 1974b), 55 p.

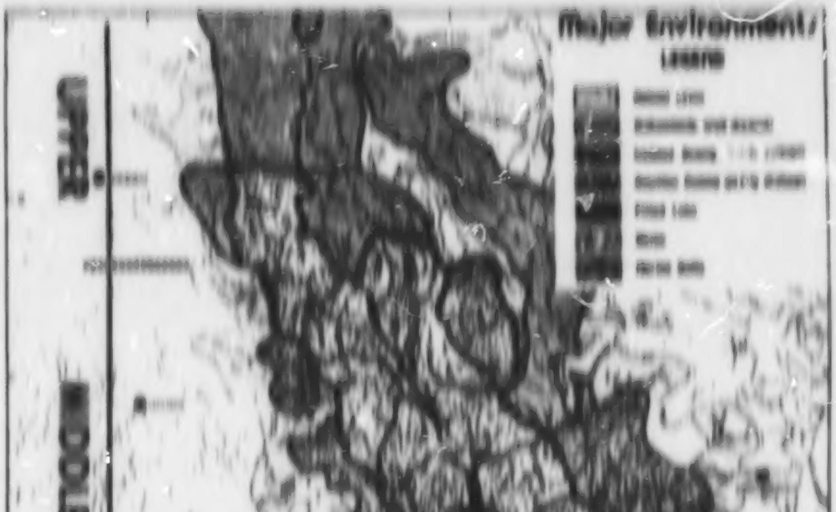

Major Environments
LEGEND
UPPER
MIDDLE
LOWER
GULF OF MEXICO

Figure 2-2. Major environments within the Atchafalaya Basin as defined by process-form-habitat relationships.

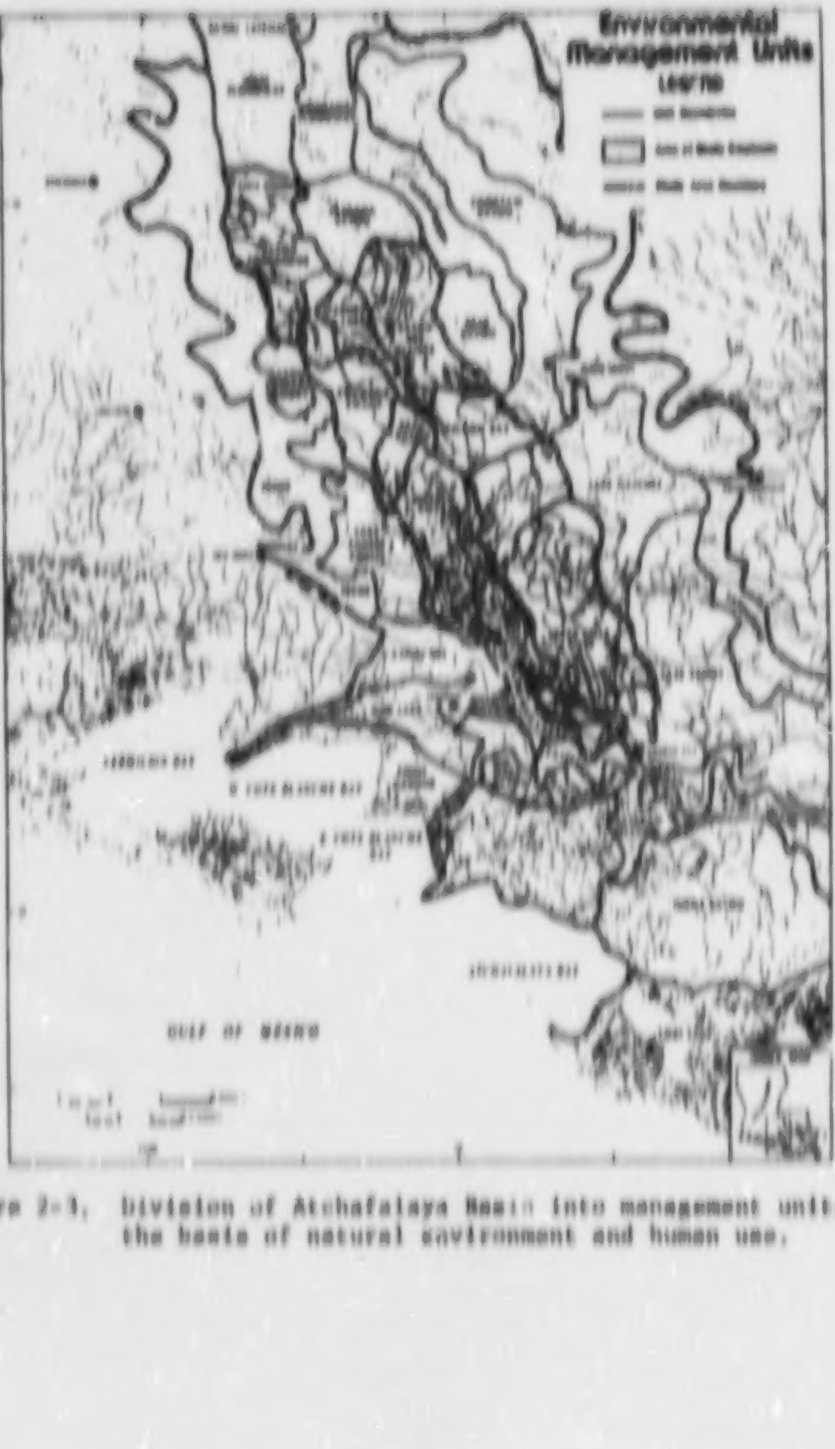

Environmental
Management Units
LEGEND
GULF OF MEXICO

Figure 2-3. Division of Atchafalaya Basin into management units on the basis of natural environment and human use.

urban, agricultural, and other land-based uses. Focusing on the floodway swamps, a method was developed to evaluate management units with regard to habitat and possible uses based on the above two controls. This involved the transformation of surface-elevation data into an elevation frequency, or hypsometric curve, representative of a particular management unit. For a given water level, extent and depth of submergence could in this manner be evaluated and provide a basis for defining management options and evaluating impact of changed water-level regimes.

Relationships between environments and hydrologic and sedimentary processes became sufficiently defined in the first study to allow development of a basic approach to water management for the overflow swamps within the floodway. This approach focused particularly on the reduction of sedimentation and maintenance of circulation. For the basin as a whole, the first phase allowed a preliminary proposal of guidelines for surface-water management as particularly related to the conflict between use of the basin as a floodway and hydrologic requirements of the overflow swamps.

The second, present study builds further on the concepts and methodology developed during the previous phase. It is, in all respects, a continuation of the attempt to arrive at a management plan that allows optimum use of the basin's resources and to analyse impact of proposed projects for extended plan development. A series of successive tasks has been undertaken. The first step involves determination, in further detail and specifically related to the basin's natural setting, of surface-water and related requirements for the natural resource complex, including fishes, wildlife, forests, and recreation; and socio-economic resource uses, including flood control, urban and industrial development, mineral extraction, transportation, and agriculture. Secondly, hydrologic characteristics of the basin are analysed for present and proposed conditions in terms of identified resource requirements. The above-derived information is then assimilated with environmental base data developed during the first study, considering constraints posed by the natural setting and overriding use requirements for flood control. Management options and present and potential conflicts are identified, decisions made concerning optimum use, and management needs specified for such use in so far as possible. Through integration of requirements for individual management units and minimization of mutual conflicts, a management plan for the basin as a whole is then developed to the extent allowed by data availability, detailing management procedures and structural needs. Because of the overriding requirement of floodway use and improvement, a number of specific goals were set for the management plan to be developed:

1) maintenance of cross-sectional area of the floodway;

2) increase over present floodway capacity;

3) provision for 1) and 2) in such a way that as much desirable habitat is preserved as possible;

4) provision for land use that is compatible with flood control and desirable habitat;

5) maximum utilization of river energy and materials.

Attainment of these goals would provide for accommodation of flood flows as well as conservation of the natural resources. Maintaining storage area involves reduction of floodbasin siltation,which is presently also a primary threat to the overflow swamp habitat. Increasing flow capacity through utilization of river energy and materials in channel development would greatly reduce the need for massive dredging and spoil disposal.

II
CONCLUSIONS AND RECOMMENDATIONS

1. Use of the Atchafalaya Basin in its present form as a floodway and associated restriction of the functional floodplain have increased flux rates of riverborne materials (including water, sediment, and nutrients) and have magnified water-level variation, contributing further to an increased energy level per unit area. The net result has been enrichment of the ecosystem and accelerated succession to a more terrestrial environment. Both results run counter to the need to preserve the basin's renewable resource values based on its aquatic habitats and to prolong useful life of the Atchafalaya Basin Floodway.

2. The principal common requirement for preserving both the flood-control and renewable-resource values of the floodway is to minimize sedimentation in backwater areas. Management strategies should, therefore, be aimed at confinement of Main Channel flows and regulation of water input into the overflow swamps in accordance with requirements for maintaining necessary stage variation, water movement, and water quality.

3. Examination of the food habits of many fishes, amphibians, reptiles, mammals, and birds reveals that crawfishes are very important organisms in the trophic structure of Atchafalaya Basin ecosystems. Crawfishes may be regarded as "key" organisms in the basin, and to a large extent, water requirements and the life cycle of the crawfish may serve as guides for surface-water regulation. A further reason for regulation of water levels is the need for sufficient dewatering in order to allow aerobic decomposition of detrital matter collected on the swamp floor.

4. Present annual variation of water levels should be maintained as much as possible in view of its role in determining plant community distribution and fish and crawfish production. Maximum and minimum stages in some management units should be reduced to enhance environmental quality.

5. Banks along the Main Channel and major distributaries have been elevated to the extent that flooding of the swamps has become largely dependent on inlets connecting individual sub-basins with the surrounding channels, thus favoring sediment transport into backwater areas. Therefore, management strategies with regard to water regulation should be aimed at controlling distributary channels rather than inflow from distributary channels into individual sub-basins. With bank modification along distributary channels, such a strategy will allow a larger proportion of water to enter individual sub-basins through overbank flow as opposed to channel flow, thus minimizing

backwater sedimentation, and will maintain unrestricted access for sports and commercial fisheries and recreation purposes.

6. Total regulation of water inflow and outflow into and from backwater areas minimizes river water diversion requirements because precipitation surplus can be effectively utilized. Such regulation furthermore allows necessary dewatering through evapotranspiration in those cases where river stage is otherwise a constraint.

7. Hydraulic geometry of the Main Channel suggests that the proposed Center Channel dimensions, particularly width, exceed those required by the present regime of Atchafalaya River discharge and load and would move the channel away from the most probable equilibrium profile. Therefore, it is recommended that enlargement of the bankfull channel cross section be limited to 7,400 m^2 (80,000 ft^2), with spoil deposited equally along both sides of the channel to achieve maximum flow confinement.

8. Analysis of management-unit hydrographs for proposed Center Channel conditions suggests that substantial water-level reductions, up to 1.5 meters (m), or 5 feet (ft), in Buffalo Cove during the spring, will occur if the project is implemented without additional structural provisions.

9. Since most probable equilibrium conditions of the Main Channel profile suggest a future rise in mean river-stage at Morgan City, since deep-water access to Morgan City should be divorced from the main river channel and its associated deltaic sedimentation, and since eastward diversion of water from the Lower Atchafalaya River is detrimental to the quality of the human environment of the Morgan City - Verret area and to quality of the Terrebonne marshes and bays, it is recommended that serious consideration be given to making Wax Lake Outlet the principal channel.

10. Many of the present regional problems arise from conflicting surface-water requirements since protective and exploitative uses of the Atchafalaya Basin's resources have become geographically intertwined in a pattern that disregards constraints placed by both the natural and human environments. Therefore, needs for land-use management are intricately connected with those for surface-water management.

11. To ensure compatability between land use and use of the Atchafalaya Basin as a floodway, the Atchafalaya Basin Floodway should be managed for protective uses to the greatest extent possible.

12. Fluvial swamps on both sides of the floodway should be managed for protective uses since they constitute high quality habitats for fish and wildlife, have high recreational value, function as

storage basins essential to present developed areas, and are a potential alternate route for flood diversion when useful life of the present floodway is ended.

13. A buffer zone, much of which may be used for silviculture, water regeneration, and aquaculture, should separate present developed areas from the pluvial and fluvial swamps in order to minimize detrimental impact from surface runoff.

14. Complexity of processes in the coastal area below Morgan City and uncertainty as to causes for present marsh deterioration prevent detailed management recommendations and require further study.

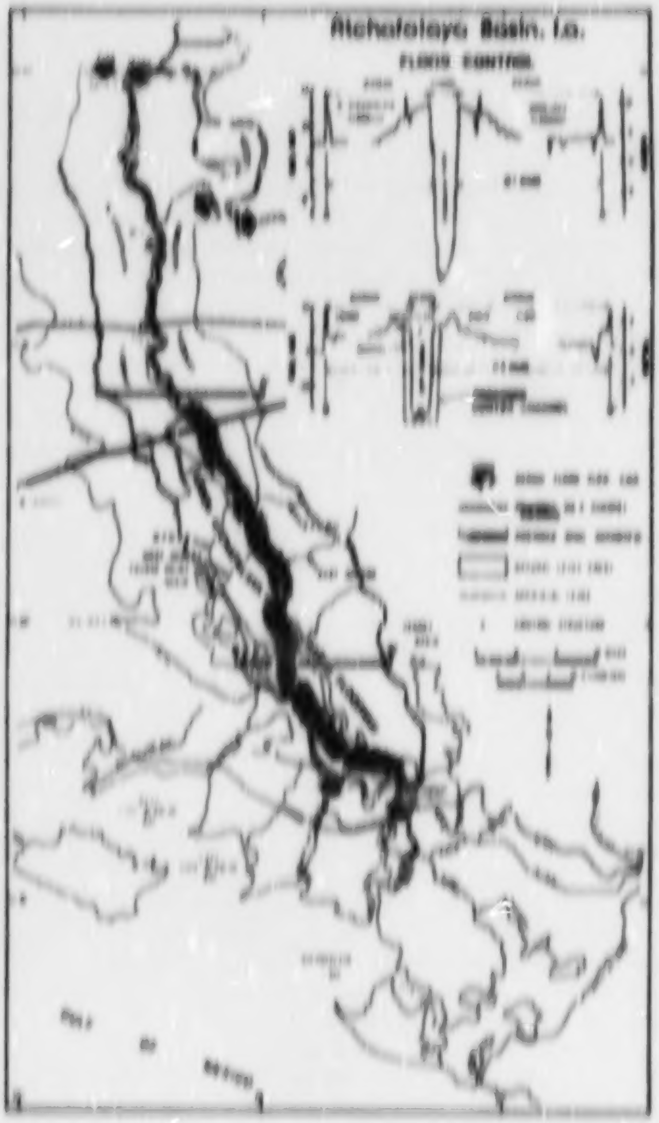
III
REQUIREMENTS OF THE SOCIO-ECONOMIC COMPLEX

Surface-water management in the Atchafalaya Basin can be looked at as a compromise between man and nature where man hopes to have the best of two worlds; that is, expansion of exploitative uses and commensurate maintenance of natural, renewable resources. As in any compromise, both sides have a set of requirements which needs to be defined before a compromise can be reached. This chapter and the two following chapters deal with the needs as specifically as possible within the constraints of the present study. Requirements as related to surface water are discussed for flood control, urban and industrial development, agriculture and rural settlement, and recreation.

Flood Control

The leveed floodway in the Atchafalaya Basin is an integral part of the flood control system for the Mississippi Valley below Cape Girardeau, Missouri. For this system to accommodate the project design flood, a volume of 34,500 cubic meters per second (cms), or 1,220,000 cubic feet per second (cfs), is to be diverted from the Mississippi River into the Atchafalaya Basin Floodway. With a projected additional contribution of 10,000 cms (350,000 cfs) from the Red River, but taking into consideration storage effects of the Red River backwater area and the floodway, the leveed floodway is required to have a total flood-carrying capacity of 42,500 cms (1,500,000 cfs). Of this total discharge, 7,000 cms (250,000 cfs) is to enter through the West Atchafalaya Floodway, 19,250 cms (680,000 cfs) through the Atchafalaya River, and 17,000 cms (600,000 cfs) through the Morganza Floodway, all to be combined in the Lower Atchafalaya Basin Floodway. The flood design requirements set in 1973 are not presently met. Excessive rainfall over much of the watershed resulted in flood conditions on the Mississippi River, with a peak discharge of 58,000 cms (2,041,000 cfs), or 67 percent of the project design flood, at the latitude of the floodway intake structures. During May, 1973, this necessitated use of the floodway to full capacity. Capacity, however, was reached at approximately 25,500 cms (900,000 cfs), or only two-thirds of the projected need. This gross inadequacy of the floodway is the result of both deficiencies in the cross-sectional area and the rate at which water can be conveyed through it.

To consider these deficiencies further, a distinction should be made between channel area and overbank area. Figure 3-1 illustrates this diagrammatically for flood conditions. In the cross-sectional diagram $A - A^1$, the channel area is physically separated from the overbank area by artificial levees, as is actually the case in the upper floodway. There the overbank area to the west is synonymous with the West



Atchafalaya Basin, La.
FLOOD CONTROL

Figure 3-1. Flood control aspects of Atchafalaya Basin. Map shows diversion of water into floodway for design flood and proposed dredging of Main Channel. Cross sections show relation of natural and artificial levees to overbank areas.

Atchafalaya Floodway; the area to the east coincides with the Morganza Floodway. In the lower diagram, conditions are shown as they generally pertain to the middle floodway from Interstate Highway 10 to Morgan City. Here the channel is separated from the overbank area only by natural levees and spoil deposits. In the downstream direction, banks are increasingly overtopped during flood stages. At all stages, river water diverts into the overbank area through four major distributary channels before being routed back into the channel at the lower end of the floodway.

Cross-sectional area is inadequate predominately in the middle floodway, the lower Atchafalaya Basin Floodway, for a number of reasons. An overall design cross section has never been attained because of settlement of the guide levees resulting from poor foundation conditions.[8] This reduces the level to which the floodflow line can be raised. Cross-sectional dimension of the overbank area has been significantly reduced as a result of sedimentation. This is inherent to the presence of a major, unconfined river attempting to build a flood plain. Construction of the floodway actually enhanced this process as it raised the annual level of overflow and limited the area of sediment distribution through confinement of the overbank area.

A second reason for rapid siltation of the overbank area is the diversion of water from the Main Channel into the flood basins to either side through the East and West Freshwater Distribution and Access Channels (Figure 3-1). Improvement of the Main Channel for flood control had been attempted until 1967 by dredging and closure of distributaries. As a result, aided by spoil deposition on the channel banks, annual flow from the Main Channel into adjacent flood basins has become increasingly dependent on the four remaining distributaries mentioned above. These channels permit 20 to 30 percent of Atchafalaya River discharge to enter the overbank area at high velocities carrying large volumes of sediment. Much of this sediment is filtered out in the backswamp areas prior to the return of water to the Main Channel at the lower end of the floodway. In addition, siltation of the distributaries occurs, necessitating annual maintenance and spoil deposition averaging 720,000 m^3 (940,000 yd^3).[9]

The contribution of the diversion channels to overbank siltation appears also substantiated when comparing changes along the west and east sides of the Main Channel and relative magnitude of flow diversion to the east and west, respectively. In the previous report,[10] it was shown that succession toward a more terrestrial environment had advanced much further in the western part of the floodway. This is in agreement with the observation that diversion into the smaller, western part amounts to 19 percent Atchafalaya River discharge at Simmesport versus 15 percent toward the eastern part.

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[8] K. L. Hebert, The Flood Control Capabilities of the Atchafalaya Basin Floodway (Louisiana Water Resources Research Institute, Louisiana State University, 1967), 88 p.

[9] U. S. Army Corps of Engineers, Preliminary Draft Environmental Statement, Atchafalaya Basin Floodway, Louisiana (New Orleans District, New Orleans, Louisiana, 1974).

Increases in elevation of the overbank area are illustrated in Figure 3-2 for a number of management units within the middle floodway. The graphs show trends of mean elevations as determined from U.S.C.E. survey ranges for the period 1930 to present. In general, elevation showed an initial rapid increase, with rates declining as the elevation increase allowed less frequent and lower depth of flooding. Two observations can be made from these graphs. The first is that much storage capacity has been lost. The second is that siltation in the next 50 years must not be expected to exceed 0.6 m (2 ft).

An indication of overall floodway siltation is given by data on suspended sediment loads carried into and out of the basin, respectively. Table 3-1 shows the average volume of sediment remaining in the floodway for the period of 1965-1971. The table shows that, on the average, 75 percent of all sand and 15 percent of all silt and clay carried into the floodway was deposited, amounting to an annual total of 28.5 million tons, or 13 million m^3 (17 million yd^3). Ignoring that most sediment deposition probably still occurs in the remaining channel-lakes, such as Six Mile Lake, and spreading this load equally over the middle floodway would amount to an elevation increase of 0.6 centimeters (cm), or 0.02 ft, per year or 0.3 m (1 ft) over the next fifty years.

In the middle floodway, the channel area also has undergone a rapid change, particularly with regard to geometry. Initially a chain of lakes,[11] the channel was ill-defined, wide, and shallow. Filling of the lakes through lacustrine delta building and associated natural levee building then increasingly confined flow, resulting in progressive scouring of a main channel. This process was further aided by dredging and spoil deposition.

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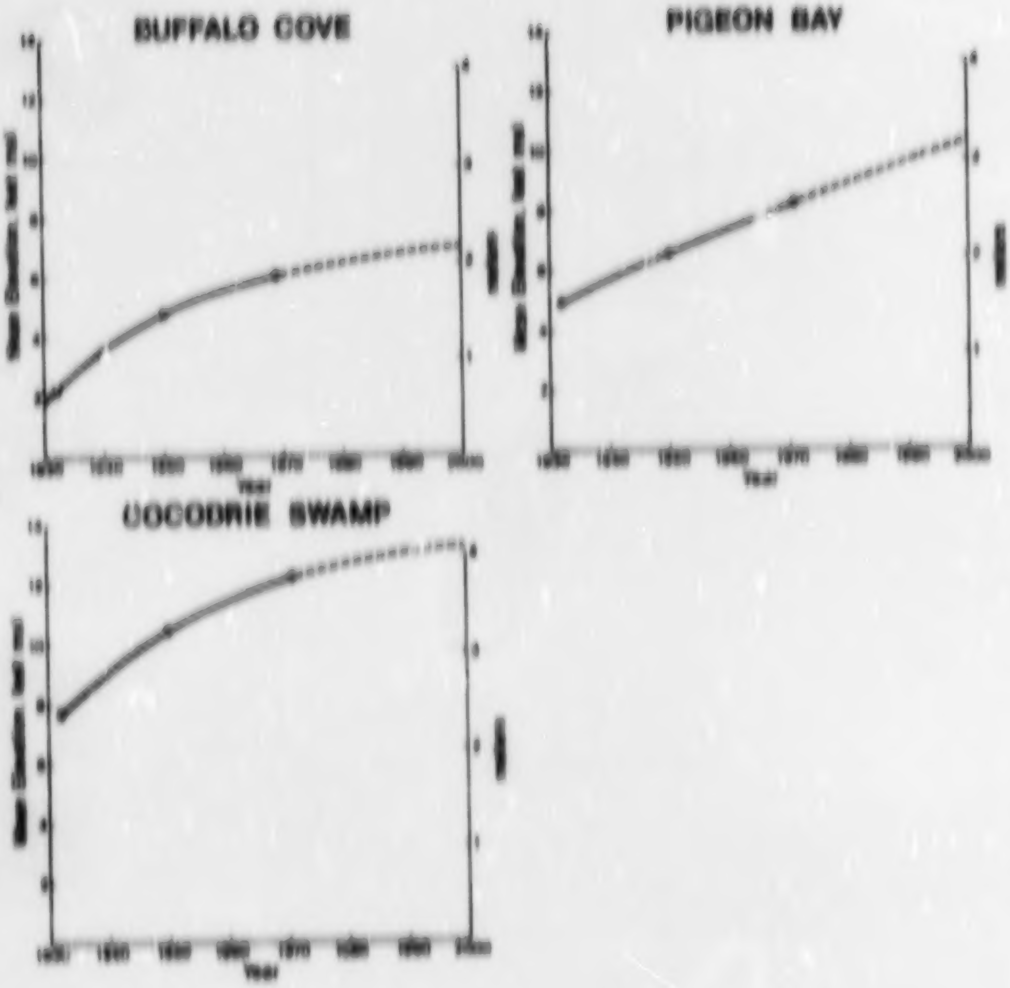
[10] Coastal Environments, Inc., 1974a, *op. cit.*

[11] H. N. Fisk, *Geological Investigation of the Atchafalaya Basin and the Problem of Mississippi River Diversion* (U. S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, 1952), 2 volumes.



BUFFALO COVE

PIGEON BAY

COCODRIE SWAMP

Figure 3-2. Changes in mean elevation for three management units.

Table 3-1. Average Sediment Balance, 1965 - 1971, for Atchafalaya Basin Floodway.[12]

	entering Simmesport in		leaving Lower Atchafalaya River		leaving Wax Lake Outlet		remaining Atchafalaya Basin Floodway	
	Sand	Silt/Clay	Sand	Silt/Clay	Sand	Silt/Clay	Sand	Silt/Clay
1000 tons	19342	67985	3696	42156	1153	15590	14493	10179
percent	100	100	19	62	6	23	75	15
percent	100		52		19		29	

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[12] U. S. Army Corps of Engineers, 1974, op. cit.

Flow-confinement and channel-formation are of major importance with regard to the rate at which water can be passed through the floodway. At a given slope, the channel area, with its greater depth and lesser surface roughness, allows a much greater rate of flow than does the overbank area. For this reason, efficiency of the upper floodway is much greater than that of the middle floodway. As was shown in Figure 3-1, the channel in the upper floodway is confined by artificial levees. Partly as a result of this confinement and partly because of channel age, cross-sectional area below bank level possibly attains approximately 9300 m^2 (100,000 ft^2) and is comparatively stable.[13] The artificial levees confine the flow at all discharges, thus helping to maintain a channel cross section that is larger than would occur under natural conditions. In the middle floodway, below mile 54, natural levees are less developed despite spoil deposition; artificial levees are absent, and time has not yet allowed development of a well-defined and large channel. Below the point where artificial levees terminate, cross-sectional area in which channel flow-conditions occur during flood is much lower in the middle than in the upper floodway, with an inherently lesser efficiency to convey floods.

To accelerate the process of channel development in the middle floodway, a dredging program was initiated in 1954 to increase channel cross section to 9300 m^2 (100,000 ft^2) below the floodflow line from mile 54 to the latitude of Wax Lake Outlet, and to 7400 m^2 (80,000 ft^2) from there to the Lower Atchafalaya River. In 1968, the so-called Center Channel had been enlarged to 5600 m^2 (60,000 ft^2) and 3700 m^2 (40,000 ft^2), respectively. Subsequently, the program was suspended for further evaluation before proceeding to dredge the 9300 m^2 (100,000 ft^2) channel.

Against the above background, the basic flood-control requirement for the floodway in the upper and middle basin can be stated as increased floodway carrying capacity. Alternative solutions, such as modified diversion routes or proportioning of project floodflows, are not considered in this section, but have been developed by Task Group 1 under the Atchafalaya Cooperative Study.[14] In turn, increased carrying capacity requires either the individual or combined increase of cross-sectional area of the two parts of the basin and an increase of flow rate. Present plans call for 1) further upgrading of floodway guide levees to increase the level to which the floodflow line can be raised, 2) dredging of the Main Channel (Figure 3-1) to 9300 m^2 (100,000 ft^2) below the project flow line from mile 54.5 to mile 105.0, and 7400 m^2 (80,000 ft^2) from mile 105.3 to mile 112.3 to provide for more efficient flow and depressed flow line during a given discharge, and 3) further confining of the channel through spoil deposition to limit overbank siltation.[15]

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[13] U. S. Army Corps of Engineers, 1974, _op.cit._

[14] _Ibid._

A second set of requirements concerns the lower floodway and focuses on the Lower Atchafalaya River, Wax Lake Outlet, and conditions at Morgan City and in the Verret Basin. Wax Lake Outlet and the Lower Atchafalaya River provide for discharge of floodwaters from the leveed floodway through the Teche Ridge into Atchafalaya Bay. During the 1973 flood, water levels attained unexpected elevations of 3.26 m (10.7 ft) mean sea level (MSL) in the Lower Atchafalaya River at Morgan City and 3.37 m (10.5 ft) MSL in Wax Lake Outlet at Calumet. Gage records at Verdunville, Morgan City, and Sweet Bay further indicate that, at that time, the floodflow-line gradient along the Main Channel increased from 0.000047 above Morgan City to 0.000086 below Morgan City. This condition suggests strongly that the cross-sectional area of the outlets was insufficient to pass floodwater through the Teche Ridge at the same rate it was arriving, thus causing build-up.

The combined cross-sectional area of the two outlets has progressively changed since completion of the Wax Lake Outlet, when its area amounted to 9200 m^2 (99,000 ft^2). The shorter distance to the Gulf has favored flow through Wax Lake Outlet so that its channel has increased in size. At the same time, the Lower Atchafalaya River filled its channel, but at a more rapid rate. The net result was a decrease in combined cross-sectional area to 8000 m^2 (85,000 ft^2) prior to the 1973 flood. During the flood the channels scoured considerably; therefore, after the flood cross-sectional area had increased again to 8600 m^2 (92,500 ft^2).

Two problems arise which relate to the extreme levels at the lower end of the floodway. The first is the direct flood threat to Morgan City. Existing floodwalls protecting the city from flooding along the Lower Atchafalaya River proved inadequate under 1973 conditions, and emergency mud boxes had to be erected on top of the walls. The second problem arises from backwater flooding. During flood conditions, tributary channels to the Lower Atchafalaya River actually become distributary channels diverting floodwaters to the east and west. To the east, the associated water-level rise thereby partially prevents drainage of the Verret Basin, for which Bayou Boeuf is the principal outlet. Since 1957, this condition has been ameliorated through construction of a levee along the east bank of Bayou Shaffer and the Lower Atchafalaya River from Morgan City to Avoca Island Cutoff, placing the diversion point further downstream, where stages are lower. However, water still is diverted through Avoca Island Cutoff into Bayous Chene, Boeuf, and Black. When Atchafalaya River flood stages are associated with heavy rainfall, as occurred in 1973, this condition results in serious backwater flooding, affecting Morgan City as well as many smaller communities along the low alluvial ridges. Wind set up of coastal water may further aggravate this situation.

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[15] *Ibid.*

A second flood-control requirement, then, is to ensure sufficient capacity of the channels carrying floodwater from the enclosed floodway, through the Teche Ridge toward the Gulf. This requirement becomes even more critical when considering that the first objective was to provide a more efficient center channel and, consequently, a more rapid delivery of water to the lower end of the floodway.

Urban and Industrial Development

Areas of urban and industrial land use are defined as "areas of intensive use with much of the land covered by structures."[16] Within the Atchafalaya Basin, such areas having populations from 5,000 to 25,000 are mainly restricted to the natural levee ridges of the Mississippi River, Bayou Teche south to Jeanerette, and Bayou Lafourche south to Thibodaux. Only along these levee ridges does natural setting meet all major requirements for urban and industrial land use, namely: 1) adequate freedom from flooding, 2) good foundation conditions, 3) adequate water or land transportation routes, and 4) a readily available supply of good quality, fresh surface or ground water. Prior to floodway construction and increased Atchafalaya River discharges, the above requirements were also met along the upper Atchafalaya River levees, where the towns of Simmesport and Melville developed, and along the lesser ridges of Bayous Teche and Black, where Morgan City is the focal point of urban and industrial development. Changes in setting in these cases now require major flood protection. Simmesport and Melville, on the margin of the West Atchafalaya Floodway, have been surrounded by ring levees, and a floodwall separates Morgan City from the Lower Atchafalaya River. In addition, deepwater access requirements have become a problem for Morgan City as a result of the developing Atchafalaya delta.

Natural levee areas that remain, although not now under urban or industrial development, meet the earlier-stated requirements, but are presently committed to agriculture, especially sugar cane. Thus, urban and industrial expansion along the levee crests is severely constrained by agricultural use and settlements, while expansion perpendicular to the crest is constrained by the presence of wetlands. Although expansion into the wetlands has occurred, notably in the Morgan City area, this must be considered extremely undesirable not only from the point of view of detrimental impact on natural resources, but also because of other reasons. Swamp soils are comprised predominantly of clays and are high in organic content so that foundation conditions are poor. Drainage results in substantial compaction and subsidence, aggravating the already-present constraints of frequent flooding and necessitating construction of levees and installation of pumping stations. Filling in the drained and leveed area with foreign soil materials after allowing several years for soil compaction is often practiced, but because of the naturally high water table and poor runoff conditions, pump drainage remains necessary. Additionally, such protected development diminishes floodbasin area and thereby storage capacity, thus increasing average water levels for periods of excessive runoff.

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[16] J. R. Anderson, et al., A Land Use Classification System for Use with Remote Sensor Data (Washington, D.C.: Geological Survey Circular, U. S. Geological Survey, 1972).

In view of the constraints on urban and industrial use of the Atchafalaya Basin, the requirements related to water management (freedom from flooding, water transportation, and water supply) should primarily concern existing development and deal with possible expansion, preferably in areas where the principal requirements are natural amenities.

Only the natural levee ridges of the Mississippi River, upper Bayou Teche, and upper Bayou Lafourche fall into both of the above categories. Water-management requirements for urban and industrial development along these ridges and related to the Atchafalaya Basin primarily concern water quality as affected by local runoff.

Local runoff from the Mississippi River and Bayou Lafourche levee ridge is directed into the Verret Basin. The Fausse Point Basin collects runoff from the upper Bayou Teche levee ridges. This not only affects water quality as a major element of the natural resources of these basins, but also concerns the value of basin water as a freshwater supply to adjacent developments. The major surface-water requirement, then, with regard to industrial and urban development along the major levee ridges is management of surface-water runoff. This requirement particularly applies to the Mississippi River area, where deepwater access permits development of heavy industry. The size and amount of discharge of Bayous Lafourche and Teche restrict development along their levee ridges to light industry because of limitations on waterborne transportation, waste treatment and disposal, and flow rates of freshwater supply.

Further heavy industrial development in the Morgan City area must be viewed as highly undesirable unless the constraints of the present setting are taken into consideration. These include limitations imposed by rich adjacent wetland and estuarine systems and the limitation of suitable areas regarding freedom from flooding and foundation conditions. Industrial development has already created a demand for additional dredging and spoil deposition through wetlands, as seen by the pending enlargement of the Chene, Boeuf, and Black Waterway. Such construction may, in turn, lead to further industrial development in highly vulnerable areas and associated urban expansion. With higher grounds along major waterways considered prime industrial sites, urban development tends to expand laterally into wetlands, rather than vertically, with known detrimental results to both natural resources and the urban environment.

Water-management requirements with regard to existing development in the Morgan City area concern primarily flood protection and navigation as described in the previous section dealing with flood control. A flood-protection requirement has developed largely as a result of flood routing, high Lower Atchafalaya River stages, and related obstruction of drainage from the Verret Basin. Proposed modifications of the Atchafalaya Floodway system do not change this requirement. Rather, the magnitude of needed protection is likely to increase. Center Channel construction as presently proposed would deliver floodwaters at the lower end of the floodway and Morgan City at an increased rate for which no provisions are planned below the Teche ridge.

Even more important is development of the Atchafalaya Delta, which will displace the river mouth seaward. As a result of this, Morgan City is displaced, relatively speaking, landward so that average river stages will increase. High subsidence rates in the area are already contributing to this trend.

Essentially, additional flood protection can be provided through two alternative or combined approaches dealing with the symptoms and the cause of the problem, respectively. The first requires a wall and levee system of greater than present height and extended to include the developed areas along Bayou Boeuf and the area facing Lake Palourde. The second requires modification of the present flood control system in order to bring about reduction of stages along the Lower Atchafalaya River, of eastward diversion from that river into Bayou Chene, and of extension of the Lower Atchafalaya River.

Water-management requirements regarding navigation in the Morgan City area concern primarily deepwater access to the Gulf of Mexico. For this access, industries in the area rely on the Lower Atchafalaya River and a dredged channel across Atchafalaya Bay. Maintaining a sufficiently deep channel has become an ever-growing problem as a result of sedimentation in the shallow bay. With fifty percent of the Atchafalaya River sediment load discharged into the bay from the Lower Atchafalaya River, a marine delta is rapidly emerging. The area of sediment deposition extends from the river mouth seaward beyond the Point au Fer reef, thus totally enveloping the present navigation channel. Maintaining a channel through an actively prograding delta is possible only, if at all, through great monetary and energy expenditure. The difficulties involved in maintaining such a channel are inherent to the process of delta building, with highest sedimentation rates occurring at the channel mouth, where flow is no longer confined and velocities decrease. Any attempt to circumvent the sedimentation process by extending the channel only displaces the problem seaward, at least as long as water depth over the area of sedimentation is less than that required for navigation. In the present case, dredging would not solve the problem unless it was continued to a distance of 40 miles offshore, where depth presently is 30 feet. Clearly, the navigational requirement is to separate deepwater access from the active river mouth.

An additional navigation requirement is the maintenance of inland waterways. Presently, navigation routes are provided by the Atchafalaya River and the two routes of the Intracoastal Waterway, an east-west route through the coastal marshes and a north-south route connecting Morgan City with the Mississippi River at Port Allen. The latter route utilizes the eastern guide levee borrow pit as far as the settlement of Sorrel, where a lock provides for crossing the guide levee.

The third management requirement for the Morgan City area concerns maintenance of water supply and quality. Fresh, ground-water supplies in the area are limited and of poor quality. Municipal water is derived from the Atchafalaya River and, in case of emergency, from Lake Palourde. Whereas quality control of the first source lies mostly beyond the Atchafalaya Basin, control over the second source is entirely dependent on management of surface-water runoff into the Verret Basin as a whole.

Agriculture and Rural Settlement

Historically, agricultural development and associated rural settlement have been concentrated along the major natural levee ridges, with relative freedom from flooding and well-drained, fertile, and easily workable soil. Settlement related to wetland-based industries, such as fishing and trapping, also concentrated on natural levee ridges, usually the lesser ones associated with small streams within the swamps. This pattern has experienced some significant modification as a result of floodway construction.

The West Atchafalaya Floodway and Morganza Floodway, although part of the Atchafalaya Floodway, are well protected from annual Atchafalaya River flooding by artificial levees. Never having been used since construction and with only simple flowage easement pertaining, the West Atchafalaya Floodway has seen widespread agricultural development and settlement, further contributing to an illusionary sense of security. Some twelve communities are existent; a 1977 census by the U.S.C.E. showed 3,524 persons residing in the floodway, 874 homes being permanent structures. Agricultural development has also followed in the Morganza Floodway, but here comprehensive easements ban all buildings for human habitation from the floodway. The Morganza Floodway is the first to receive emergency diversion from the Mississippi River and has been used in the past.

Within the Lower Atchafalaya Basin Floodway, agriculture and settlement were mostly abandoned as Atchafalaya River discharge increased up until 1965. Settlements became limited mainly to the previously existing communities of Butte La Rose and Atchafalaya, both on the old Atchafalaya River natural levee ridge. Maintenance of these settlements was possible through extension of the Atchafalaya River levees so that the settled areas became an extension of the West Atchafalaya Floodway, with flood threats limited to conditions of backwater flooding and use of the latter floodway.

Displacement has resulted in new strip settlements along the floodway guide levees and associated service roads in the Verret and especially in the Fausse Point Basin. This raised additional problems in that these newly settled areas were more distant from the natural levee ridge and thus more flood prone, adding to existing agricultural demands for drainage of the swamp-natural levee interface of these basins.

Recently increased surface elevations within the lower floodway resulting from spoil deposition and flood-related sedimentation have invited new attempts at settlement and agriculture since only simple flowage easements are in effect. In the past five years, new settlements were established along the West Access Channel and along the Mongoulois part of the Main Channel. Further, the higher spoil areas support herds of cattle and, in some cases, are farmed, particularly for soybeans.

Outside of the floodway system, most of the land used for agricultural purposes occurs on the margins of the Verret and Fausse Point Basins, on the natural levees of the Mississippi River, Bayou Lafourche and Bayou Teche, and in the upper Verret Basin north of Highway 190. Extensive agricultural development is also present in the area wedged between the Atchafalaya and Mississippi Rivers north of the Morganza Floodway, called the Point Coupee Loop, which is surrounded entirely by artificial levees. Smaller-scale development and rural settlement has occurred on narrow-levee ridges, such as along Bayou Black, and on those transecting the Verret Basin and related to former, minor distributaries. Barely above the level of adjacent swamps, the lands and settlements of the latter type are highly vulnerable to flooding as a result of two processes, backwater flooding and, ironically, drainage improvement.

Backwater flooding of the Verret Basin was discussed earlier (see page 27) with regard to contributive factors. In the Fausse Point Basin, backwater flooding relates to insufficiency of the

Charenton Canal as a drainage outlet, in particular during the periods of wind setup in the coastal bays.

Drainage improvement of natural levee ridges tends to have two effects. It makes existing agricultural areas more desirable for urban and industrial development and opens up new marginal areas for agriculture along the levee-swamp interface. As a result of both, agricultural development tends to expand or shift toward that interface where marginal conditions again require drainage improvement. Such improvements will accelerate runoff from the natural levee areas, increasing rates at which water is contributed to the swamp basins, which have an inherently poor drainage network. Consequently, average water levels are raised. In addition, storage capacity of the swamp is reduced by the reclamation of its margins and has the same effect.

Against the above background, water-management requirements can be considered. As in the case of urban and industrial development, these concern primarily flood protection and water quality, with the former preferably limited to presently developed areas and potential areas that are naturally suitable. With regard to flood protection, the major requirement appears to be minimization of backwater flooding related to Atchafalaya discharges. This demands to the greatest extent possible separation of the Verret Watershed from the Lower Atchafalaya River. In combination, adequate flood protection may require low flood dikes unless major channelization of swamp streams is undertaken to allow rapid removal from the basin. The latter must be considered in direct conflict with the natural resource base. A forced drainage district has been planned along Bayou Black in Terrebonne Parish.

Runoff presents a water quality problem not only with respect to the natural environment, but also in regard to the freshwater supply represented by waters of the basin. Management for quality control of runoff into the swamps from the settled and agricultural lands within the floodway north of U. S. Highway 190 and flow from the major levee ridges marginal to the Verret and Fausse Point Basins are a second major requirement.

Proposed enlargement of the Main Channel of the Lower Atchafalaya Basin Floodway and concomitant lowering of flood stages may well invite agricultural development into that area, even though most lands are only marginally suited for this and can be developed only at great expense. Yet, this remains feasible even to the extent of settlement. Seventy-five percent of the lands are in private ownership, and only simple flowage easements were acquired by the U.S.C.E. over small, scattered areas which were not subject to frequent overflow as of 1928. From this appears a third requirement, that of ensuring compatibility between land use and function of the floodway.

Oil and Gas

Exploration for oil and gas is among the human undertakings that have brought about major environmental change in the Atchafalaya Basin. In the absence of trafficable ground, access to drilling sites is invariably obtained by dredging a canal from the nearest waterway. Successful drilling has often been followed by pipeline installation, requiring additional canals. As a result, a dense and seemingly random network of canals and spoil banks has been superimposed on topography and hydrography of both the swamps and marshes.[17] Their effect on the natural resource base has never been fully assessed, though numerous examples of detrimental change can be identified. These include excessive sedimentation in backwater areas and infilling of lakes, obstruction to water movement resulting in water quality problems, and changes in hydroperiod toward insufficient dewatering or excessive drainage.

One set of requirements for surface-water management relates directly to the above impacts and can be summarized as the integration of present and future canals into the natural system. Even though drilling success has yielded increasingly to failure in the past five years, indicating only limited reserves, it must be assumed that drilling will continue for some time. This means that unless more costly means of exploration, such as directional drilling, are utilized, canal dredging will continue in order to provide access and pipeline routes. While policies established by the Louisiana Wildlife and Fisheries Commission have been in effect since 1970 concerning closure of canals at intersections with major sediment-carrying channels and provision of gaps in spoil banks, the principle of a straight line being the shortest distance between two points remains applied to selection of canal locations. In this regard, a requirement, clearly, is the selection of routes that adhere to the hydrographic grain of sub-basins to be traversed. On a larger scale, this may become increasingly important where major lines connecting offshore fields and onshore markets must cross the Atchafalaya Basin.

A second requirement relates to possible assets of the canals. As a result of sedimentation, many lakes and streams have decreased in size and depth to the extent that they no longer serve as a fish habitat during the late summer and early fall, when water levels are low, water temperatures are high, and oxygen concentrations decrease significantly. Because of depth and contained volume of water, canals appear less affected by these constraints and are known to provide good sports fishing. Because low water conditions isolate many of the canals from the swamp system as a result of spoil banks, integration of present and future canals into the swamp system with regard to both access and circulation is seen as a requirement to offset habitat losses through sedimentation and especially through lowering of water levels as a result of Center Channel construction.

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[17] Coastal Environments, Inc., 1974a, *op.cit.*

A third requirement concerns access to drilling sites and oil field installations. Weight of this requirement with regard to future drilling and associated movement of equipment can be assessed only on the basis of known and possible reserves. This cannot be evaluated here except to point out the decline in productive new wells relative to the number of wells drilled. There will remain, however, the need for maintenance of wells and other oil field installations even if no additional wells are drilled. Yet, no systematic evaluation has been made with regard to boat traffic related to mineral industry activities as to numbers, draft, and routes used in present operations. Therefore, no specific requirements can be stated concerning navigation related to the mineral industry.

Recreation

Recreation in the Atchafalaya Basin hinges on the relatively unspoiled wilderness characteristics prevalent in the area. The basic requirement, then, for maintenance of the recreational attractiveness of the basin is the preservation of the existing natural amenities. Major forms of recreation in the basin include hunting, fishing, crawfishing, pleasure boating (including canoeing), picnicking, camping, and nature study (including birdwatching). Because of the wet character of the basin, most recreation is water-oriented or water-related.

Sport fishing is probably the most popular recreational activity. There are few weekends in the year when a fishing tournament or rodeo is not held in some area of the basin. This area is nationally known among enthusiastic fishermen for its ability to produce great numbers of large-mouth bass. Species like bluegill, crappie, warmouth, red-ear, and catfish are also taken in good numbers by both boat and bank fishermen.

The popularity of fishing in the basin attests to the abundance of sport fishes in these waters. Large standing crops of fishes can be attributed to the immense area of aquatic habitat and to the annual overflow of Atchafalaya River water into backswamp areas,which stimulates fish reproduction and enhances overall productivity. Preservation of these characteristics is essential for maintenance of the presently high value of the recreational fishing resource.

Crawfishing is a pastime which is almost unique to Louisiana. The pursuit of "mudbugs" is often the basis for family outings during the spring season when many avid crawfish-seekers may be seen lifting set nets (similar to crab nets) hopefully full of the tasty crustaceans.

Crawfish are sought throughout southern Louisiana in swamps, marshes, roadside canals, and in almost any place where there is shallow water with much aquatic vegetation. That portion of the West Atchafalaya Floodway along U. S. Highway 71 is a favorite recreational crawfishing area. The borrow pit canals inside the floodway protection levees and the large swamp area of the Grosse Tete-Verret-Palourde Basin east of the floodway are also heavily used.

The recreational crawfish harvest is quite large. Soileau, *et al.* estimated the 1971-1972 sport catch at 1,117,000 pounds, and their study area included only the floodway between U. S. Highways 190 and 90.[18] The sport crawfish catch throughout the natural Atchafalaya Basin could be twice this amount, and in some years may rival the commercial catch in size.

The requirement for maintaining the value of recreational crawfishing in the Atchafalaya Basin is the preservation of existing aquatic habitat conditions and continuation of natural water-level fluctuation in backswamp areas. The life cycle of crawfish is intimately related to fluctuating water levels and is further described in another section of this report (see *Requirements for Crawfish Production*).

Hunting (see sections of report on Game Animals and Waterfowl) for such game as deer, rabbits, squirrels, and ducks is a major recreational activity in the basin. Recreational hunting depends on availability and abundance of game which, in turn, requires appropriate habitat types. Thus, habitat preservation is a basic requirement for hunting recreation.

Most land in the basin is privately owned and is leased by owners to private hunting clubs. As a result, many would-be hunters who cannot afford to join hunting clubs or who hunt too infrequently for joining a hunting club to be of value have no place to hunt. Establishment of state-owned public hunting grounds in the basin would greatly benefit this group.

Other types of recreation in the Atchafalaya Basin, such as pleasure boating, picnicking, camping, and nature study, are founded on the scenic and wilderness qualities of the swamp forests. Cypress trees with their buttressed trunks and lacy foliage, often heavily draped with Spanish moss, contribute greatly to the beauty of the swamp. Possibilities of observing wildlife, such as herons, raccoons, and an occasional alligator, add to the attractiveness of swamps. Wilderness and scenic qualities are the main attractions of the basin to canoeists, picnickers, and many campers. Many hunters and fishermen maintain more or less permanent camps built on small ridges or rafts from which they base their operations.

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[18] Lawrence J. Soileau, *et al.*, *Atchafalaya Basin Usage Study, Interim Report* (Louisiana Wild Life and Fisheries Commission, New Orleans, Louisiana, 1973) 44 p.

Opportunities for both formal and informal nature studies are abundant in the basin. The life history and ecology of many of the basin's inhabitants have never been accurately described. Many features of the lives of invertebrates, fishes, amphibians, reptiles, birds, and mammals await elucidation by students of natural history.

Recreation in the Atchafalaya Basin, then, has its foundation on the existing natural wilderness and fish and wildlife resources. This requirement for maintaining recreational values is the preservation of the existing resources upon which recreation is based.

IV
FORESTS OF THE ATCHAFALAYA BASIN

General Nature of the Atchafalaya Basin

The forests, marshes, lakes, estuaries, bayous, rivers, pastures, croplands, and towns which cover the area of the Atchafalaya Basin can all be viewed collectively as a single ecosystem. In this ecosystem, there are thousands of various kinds of organisms with many thousands of interactions or relationships among them. All of these organisms have particular requirements for space and other resources. Due to the widely varied preference in space and other resource needs, few organisms are distributed uniformly throughout a complex ecosystem, but are instead discontinuously distributed in places where these requirements are met. This sorting-out process leads to formation of associations of plants and animals which have related space and other resource needs. Fortunately, not all of these organisms are of equal importance in determining the overall character of the ecosystem so that we can infer much about its dynamics from considerations of a smaller group of abundant life forms.

Plant communities of the Atchafalaya Basin are of basic importance in the ecosystems of which they are components. The vegetation uses the energy of the sun in its production of plant matter, which is the energy base of all other elements of the ecosystem. The architecture or spatial structure of the ecosystem is largely determined by the growth forms of the plant species that dominate a given area. Vegetative types have an important effect on the water budget of an area through processes such as interception of rainfall, evapotranspiration, and flow retardance.

There is very little known of a detailed or quantitative nature about an ecosystem comparable to the Atchafalaya Basin. For this reason, we can make only certain general inferences based on observation of processes that take place in such a system. In the following paragraphs, a broad sketch of the general nature of the Atchafalaya Basin will be presented.

Most of the higher and better-drained lands of the Atchafalaya Basin that are not subject to frequent inundation have been cleared and are under use for agricultural or other human purposes. The remaining lands are for the most part forested by many different types of tree associations. Except for black willow, there have been no virgin tree stands in the entire area since the last phase of the industrial cypress lumbering era, which drew to a close during the 1930 to 1940 decade.[19] Many of the native hardwood stands on higher grounds had been taken prior to that time. Few accurate descriptions exist as to the nature of these original stands of trees or of their associated organisms; although this is of interest to the natural historian, it is largely irrelevant to the forest conditions of the Atchafalaya Basin today.

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[19] Ervin Mancil, An Historical Geography of Industrial Cypress Lumbering in Louisiana (Ph.D. Dissertation, Department of Geography and Anthropology, Louisiana State University, 2 volumes, 1972).

The forest communities of the basin range from bottomland hardwoods to cypress-tupelo. Each community type will be considered in some detail in later sections, but it is important to point out that all of them have certain basic similarities. The major tree species are deciduous, for instance, and this fact gives a seasonal pulsation to numerous processes over the whole area. Each tree species has its own distinct form of growth, yet all of them have analogous characters leading to a generally similar series of levels of stratification. Each has a soil zone which is densely root-penetrated. Above the soil is the zone of understory vegetation and tree boles. While the forests are flooded, there is an aquatic zone over the soil. All tree communities have an uppermost canopy zone of branches and leaves. There is a continual cycling of material within and between these strata. Branches, bark, and leaves are continually shed from the canopy and fall to the forest floor. Lichens on branches and bark may be important sources of fixed nitrogen. Similarly, bark is continually shed from tree boles, and materials are shed from the understory elements onto the soil surface. Numerous organisms find habitat and niche in the various strata and add their part to the flow of materials. Birds, insects, mammals, amphibians, and other organisms which exist in the canopy layer also provide a continual stream of materials in the form of excreta, molted exoskeletons, and various other substances. These are mingled with the plant debris littering the forest floor and form a substrate for a wide range of decomposer and detrital-feeding organisms. Additional nitrogen may be fixed in the process of decomposition by certain fungi.[20] Animals of many kinds on the forest floor are important agents in the transformation of this debris through activities such as burrowing, digging for food, or otherwise moving the material.

Forest communities of the Atchafalaya Basin exhibit various forms of stratification depending on community type. The cypress-tupelo community, for instance, is often made up of a few age classes of trees since conditions for germination are best during occasional dry years. The even-aged stands, then, may have a relatively well-defined stratification of two or three distinct generations of trees. In the cypress-tupelo community, lianas are largely absent, which is a marked contrast to the architecture of this forest type as compared to better-drained sites. The most abundant epiphytes in the canopy zone are lichens of which a variety of fruticose forms are very numerous on the higher branches. Spanish moss is a common epiphyte, especially in the vicinity of openings in the canopy such as lakeshore situations. On the boles of the trees, encrusting lichens are numerous and mosses are common. In crooks of the bole, mosses are especially prominent along with the resurrection fern (*Polypodium polypodioides*). Numerous fungi occur as well both on the canopy branches and the bole. A notable example is the pecky cypress fungus (*Stereum* sp.), which can extensively consume the woody tissue of baldcypress. Many hollow tree trunks are created by fungi and other agents, and these hollows must be regarded as important architectural elements of the system because of the habitat they provide for various organisms. There is a complex association of wood-boring organisms, many of which are prey of other species, such as the several kinds of woodpeckers which bore into the wood, thereby creating other habitat opportunities for many other species.

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[20] B. W. Cornaby and J. B. Waide, "Nitrogen Fixation in Decaying Chestnut Logs" (Plant and Soil, Volume 39, 1973).

Another aspect of the ecosystem can be termed its temporal structure, which refers to its sequence of regular events through a typical year. The river flood cycle is a major element of the temporal structure. The yearly cycles of leaf fall, flowering, fruiting, and germination, which vary widely among the different plant species, are all part of the overall temporal structure. The life cycles of animals, which are tremendously varied, are important time-structure elements as well.

The Atchafalaya Floodway represents a restricted artificial flood plain of the Mississippi - Red River system. Prior to artificial control, these rivers spread their floodwaters over a large area of southern Louisiana. Because the area of flooding was large, the rates of material and energy flux at most sites were relatively small. As the artificial levees along the Mississippi River were built, the movement of floodwater became increasingly restricted and eventually was diminished to the small area of batture lands lying between the levees and to the Atchafalaya River basin. With the creation of the Atchafalaya Floodway, the area over which floodwater could spread was even further restricted.

As a consequence of the diminished area of land over which floodwaters can spread, the sedimentation rates have risen, as has the flux rate of all other materials carried by the river system. The artificially achieved shrinkage of the floodplain area has impressed its impact on the ecosystem of the Atchafalaya Floodway area primarily through increased rates of flux of riverborne materials entering the area.

Water is the most abundant material carried into the floodway and, due to the restrictions on its spread caused by the protection levees, this water exhibits an amplified stage variation in comparison to pre-floodway conditions. This amplification of flood hydrographs has been responsible for much habitat change in the floodway.

It is important to consider, however, the other materials moving through the river system in addition to the water. Suspended solids are second in amount to water in the materials transported into the floodway. Bryan et al. found an average concentration of about 0.4 grams per liter (g/l) in mainstem Atchafalaya water at mile 77.3.[21] This is in agreement with data (Figure 4-1) presented by the U. S. Army Corps of Engineers in its environmental impact statement.[22] From this, it appears that the amount of suspended matter being carried into the system is declining. This is probably due to increasing numbers of reservoirs throughout the upstream segments of the Mississippi-Red River drainage basins.

The third most abundant material moving down the river is the dissolved solid matter. According to the U. S. Army Corps of Engineers,[23] the dissolved solids over the five-year period 1968 - 1973 were generally in the range of 190 - 240 milligrams per liter (mg/l). In this case, there are not sufficient data to show if there is a long-term trend in dissolved solids concentration. This dissolved material includes a wide range of substances, including many important nutrients. The reduced surface area of the artificial flood plain again means a higher flux rate per unit area than that which existed before human modification. This has, in effect, enriched the ecosystem of the floodway with important vital materials.

The fourth most abundant class of materials in transport in the water is the organic matter. Bryan et al. report an average of 7.9 mg/l of organic carbon at mile 77.3, which means that total organic matter is about two times that value, or roughly 16 mg/l.[24] Again, flux rate of this material, which represents both food and potential nutrient matter in the floodway ecosystem, is greater now than before the floodway existed.

Not only have material fluxes increased due to artificial confinement of floodwaters, but the energy of the moving water is also greater per unit area than it would be without the floodway. Much of this energy contributes to biological processes by various means. This is the basis of the well-known fact that flowing water systems are more productive than static water systems. This fact seems to arise primarily through the higher circulation rates of vital materials, such as nutrients and dissolved gases, in flowing water. Construction of the floodway, then, must have led to increased productivity for the several reasons given above. Such increase augmented

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[21] Bryan, et al., 1974, op. cit.

[22] U. S. Army Corps of Engineers, 1974, op. cit.

[23] Ibid.

[24] Bryan, et al., 1974, op. cit.

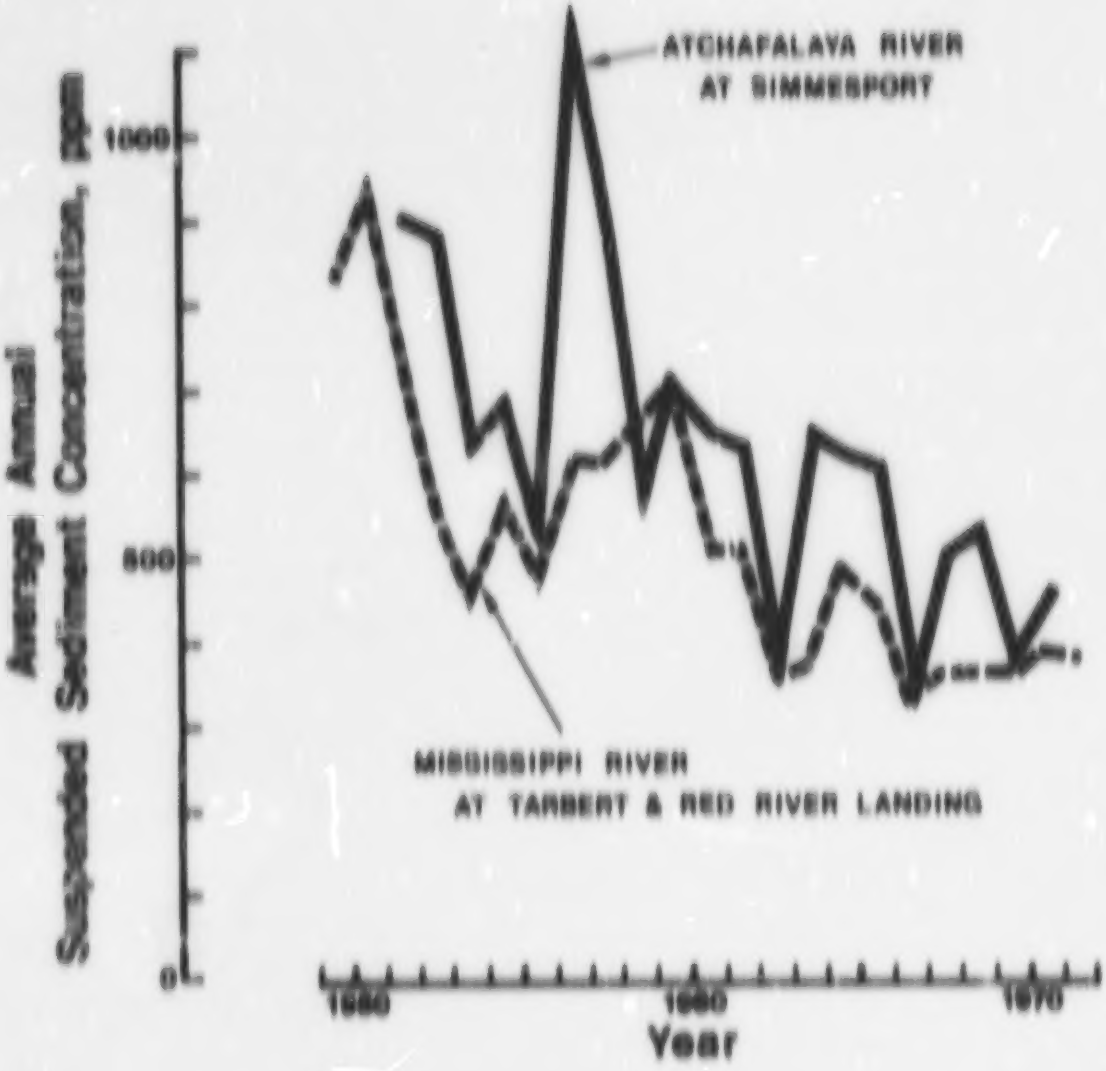

Figure 4-1. Trends of suspended sediment concentration for the Mississippi River and Atchafalaya River.

an already-high productivity, which has as its primary reason shortness of the food chain: detritus - crawfish - large predators.

With regard to the area of the Atchafalaya Basin which is outside the floodway, much the opposite kinds of conditions have come to prevail since these lands became artificially separated from the river flood plain. The lands at lower elevations now are flooded largely from rainwater falling directly upon them or entering them from the agricultural drainage districts or urban developments which occupy higher ground. Such flooding does not lead to the extreme stage variation characteristic of the floodway. Suspended matter can be high at certain times in the runoff from the developed areas, but it is far less than the levels in the highly turbid river waters which formerly entered these areas. Dissolved solids may be high, particularly where argicultural and urban runoff are high; however, total quantities of these contributions are far less than those in flux through the river waters of the floodway. Most organic matter is produced within these systems since they have no important allochthonous contribution, as does the floodway. Water movement through these systems is not nearly as energetic as in the floodway due to the much lesser volume of flow.

It is against this background of fundamental conditions that we must view the Atchafalaya Floodway and isolated swamp ecosystems. The forests of these areas vary largely in accordance with these conditions, and in the remainder of this discussion, we shall emphasize the following factors which exert considerable regulating control on the forest ecosystems.

1) Hydroperiod. This refers to the duration of flood conditions at a site. In the floodway, low-lying areas may have prolonged hydroperiods during an average year. Outside the floodway, isolated swamp areas are less likely to have long flood duration since they have mainly pluvial water sources. The nature of flooding, particularly its timing, is a primary determinant of tree species distributions.

2) Sedimentation. This refers to the degree or rate of sediment accumulation at a given site. Understandably, this is quite different for low-lying sites within the floodway than for those outside of it. Sedimentation rates are also a primary determinant of tree species distributions.

Conditions in the Bottomland Forests

Most of the bottomland tree species begin to develop leaves and flower in the period from March to April. For most species, fruit maturation occurs in the fall, and germination is in the spring. However, the species following this schedule are largely those characteristic of the lowest hydroperiod lands. Species which characterize longer hydroperiod lands often have a different schedule. Black willow and cottonwood both show a similar reproductive strategy that differs from the other bottomland hardwoods. Both may begin to flower relatively early (February - March) and then produce mature seeds very shortly afterwards (April - July). Both have seeds that will germinate almost immediately after arrival at a suitable site on moist mineral soil. The seeds do not remain viable for any appreciable length of time in dry conditions, but may remain viable for several weeks in water. Red maple has a schedule of early flowering (February), early seed maturation (March), and germination in early summer. Baldcypress flowers early (December - January) and produces ripe seeds later than most trees of the basin (November - December). Baldcypress seeds apparently germinate best in spring, but since the swamp is usually flooded at this time, good years for germination are few and far between. Baldcypress seeds are known to remain viable in water for extended periods and may germinate over a greater span of time than most species. Water tupelo develops flowers and fruit simultaneously with most other species of the area, but its germination takes place in mid-summer. The later period of seed germination for black willow, cottonwood, red maple, and water tupelo obviously is a favorable adaptation for floodplain species since soils are less likely to be flooded at this time.

When floodwaters from the river begin to flow through the overflow swamp areas, the processes that take place are complex. Initially, the input of rainfall surplus is high, and the floodwaters are diluted with this source. By spring, however, transpiration, evaporation, and interception have increased to the point that rainfall surpluses do not exist, and floodwaters are the primary input to continued flooding.

In the initially flooded swamplands, there is frequently a heavy organic surface litter left over from the fall leaf abscission and from all earlier leaf, branch, or trunkfall remains in varying stages of decomposition. This high biological oxygen demand leads to rapid development of an anaerobic soil profile and low oxygen in the water. Even in such early waters typical of the cooler months of the year, oxygen may be no more than 3 - 5 parts per million (ppm). As temperatures rise and production and respiration both increase, oxygen frequently declines to still lower values, suggesting that respiration is exceeding production in the water column. In areas of extensive water hyacinth mats, there is a high demand from the dead parts of the mat, while the plant cover greatly interferes with gas exchange between the water and atmosphere. Such waters become low in oxygen quickly.

Estimates of primary production from swamp systems of the kind found in the Atchafalaya Basin have not been made. Studies in the swamp basin above Lac des Allemands, a short distance to the east of the Atchafalaya Basin, by personnel of the Center for Wetland Resources have shown that waters of streams draining the swamps have much higher active chlorophyll *a* concentration than other waters studied in the coastal zone. Day *et al.* stated that this suggests that such swamp systems are "highly eutrophic."[25] The isolated swamps of the Atchafalaya Basin are probably comparable in character, whereas the floodway swamps are more limited in phytoplankton biomass due to highly turbid waters. Diurnal oxygen curves in the Lac des Allemands swamp waters showed little daily fluctuation, and oxygen was generally low despite the high phytoplankton biomass. Day *et al.* described this as a "strongly heterotrophic aquatic system due to the large quantities of dissolved and total organic carbon in the waters."[26]

There are many areas in the Atchafalaya Basin where the high nutrient flux of the system is evident. Among these are the areas of prolific and recurrent water hyacinth blooms, which become anoxic in warmer months. The Buffalo Cove area has been cited as a case of this type in earlier work.[27] In this area, a chronic and recurrent water hyacinth bloom at times has covered an area of 51.8 square kilometers (km^2) or 20 square miles (mi^2). Fish kills and kills of crawfish that have been taken in traps are problems in such areas.

Coleman reported that soils of the poorly drained swamps contain mineral pyrite (FeS_2), ferrous sulfide (FeS), and vivianite ($Fe_3P_2O_8 8H_2O$).[28] Thus, to some extent, the soil acts as a sink for iron, sulfur, and phosphorus through the formation of these substances. From this, it is apparent that phosphorus and iron are not likely limiting. Nitrogen may be the principal limiting element in most Atchafalaya Basin systems.

Water hyacinth is a dominant plant in many areas of the basin. In the Buffalo Cove area, for instance, water hyacinth has in recent years occupied most of the long hydroperiod habitat, an area of approximately 51.8 km^2 (20 mi^2). The lower part of the Upper Belle River unit is also an area of chronic water hyacinth cover over an even wider area. In these localities, the water hyacinth cover is virtually 100% during some years. In the marshes flanking the Atchafalaya River mouth in western Terrebonne and St. Mary Parishes, extensive water hyacinth cover has developed within and replaced freshwater marshes during recent highwater years.

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[25] John W. Day, *et al.*, "Flora and Community Metabolism of Aquatic Systems within the Louisiana Wetlands," in *Environmental Assessment of a Louisiana Offshore Oil Port and Appurtinent Storage and Pipeline Facilities* (Volume 7, Technical Appendix 6) 39 p.

[26] *Ibid.*

[27] Coastal Environments, Inc., 1974b, *op. cit.*

[28] James M. Coleman, "Ecological Changes in a Massive Fresh-Water Clay Sequence," Gulf Coast Association of Geological Societies, *Transactions* (Volume 16, 1966).

Areas of chronic water hyacinth cover within the floodway appear to represent areas of a great amount of river water throughflow. Hyacinths respond to flowing water conditions by vigorous growth due to the constant renewal of root exposure to the water with its nutrient substances. Rafts of hyacinth are trapped and held in the tree-covered swamp areas as a result of jamming against tree trunks or understory vegetation. As these continue in rapid growth, the area of cover may expand to fill the entire flooded swamp basin. During low water periods, the matted hyacinth may be killed from desiccation in areas which are exposed to drying conditions, but in lower-lying places they persist throughout the year. As waters rise again in the swamps, the hyacinths may increase in cover at virtually the same pace as the spread of flooding.

While mats of hyacinth can develop rapidly in flowing water conditions, it must be mentioned that the growing mat increasingly becomes a retardant to water flow due to the heavy root systems which dangle as low as three feet beneath the mats. Energy is dissipated through friction, turbulence, and bending motion imparted to the roots as water passes through beneath the mat; consequently, flow speed is reduced.

Timmer and Weldon, among others, have shown a high water loss for water hyacinth mats, averaging 3.7 times higher than an open water surface.[29] Why this is so is unclear, but it must be related in part to the stomatal structures described by Penfound and Earle, who report that their average number, 120 per square-millimeter (mm^2), is typical of other plants, but that their aperture size, 12 microns (μ) by 37 μ, is much larger than a typical value for other plants. Thus, the area of apertural opening is high. For this reason, they conclude that, ". . . it is evident that the water hyacinth, with a moderate number of very large, evenly distributed stomata, is well-equipped for rapid diffusion of gases."[30]

Another interesting aspect of water loss from floating hyacinth mats is that it varies according to water flow. Rogers and Davis showed that transpiration per plant was 175 milliliters (ml) in static water and 225 ml in flowing water.[31] This was measured under controlled conditions using uniform-sized plants. Under natural conditions, the water loss in flowing water areas could be even greater since Penfound and Earle observed that in flowing water, hyacinth stands tended to have larger leaves with greater surface area.[32] Since Timmer and Weldon's estimate of water loss from hyacinth cover is based on static water measurements,[33] it is likely that flowing water situations, such as those of the Atchafalaya Floodway, experience even greater water losses.

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[29] C. E. Timmer and L. W. Weldon, "Evaporation and Pollution of Water by Water Hyacinth," Hyacinth Control Journal (Volume 16, 1967).

[30] W. T. Penfound and T. T. Earle, "The Biology of the Water Hyacinth," Ecol. Monogr. (Volume 18, 1948).

[31] H. H. Rogers and D. E. Davis, "Nutrient Removal by Water Hyacinth," Weed Science (Volume 20, 1972).

The ability of water hyacinth to absorb large quantities of nutrients has been noted by several workers. Rogers and Davis noted that a single plant could absorb between 5.3 and 19.8 milligrams (mg) of nitrogen (N) per day,[34] depending on the concentration of N in the nutrient medium. In simulated flowing water systems, they found absorptions increased to a range of 9.9 - 20.8 mg per plant per day. In a sewage effluent, they noted absorption of N at a rate of 6.6 mg per plant per day in static water conditions. Phosphorus (P) was absorbed at rates ranging from 1.1 - 3.1 mg per plant per day in flowing water.

Shamsuddin showed daily absorption rates of N per plant to be 2.6, 2.4, and 3.5 ppm in media to which 50, 100, and 250 ppm of N were applied, respectively.[35] He showed orthophosphate daily absorption rates per plant to be 0.6, 0.4, and 0.7 ppm in media to which 50, 100, and 250 ppm of orthophosphate were applied, respectively. The N:P uptake ratio ranged from 5 - 6 in these experiments, corresponding to Boyd's estimate[36] that water hyacinth plants contain about six times as much nitrogen as phosphorus.

For these reasons, water hyacinth has been considered on numerous occasions as a potential contributor to wastewater treatment.[37,38,39] According to Webre,[40] an experimental plant of this kind is under construction at the National Space Technology Laboratories (NSTL) under the direction of B. C. Wolverton. He has noted not only significant nutrient uptake, but also that pesticides and heavy metals can become concentrated significantly by hyacinths growing in polluted waters. The NSTL programs presently project the growth of water hyacinth on sewage discharge waters with subsequent fermentation of the hyacinth biomass to yield methane gas and a composted fertilizer material.

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[32] Penfound and Earle, 1948, *op. cit.*

[33] Timmer and Weldon, 1968, *op. cit.*

[34] Rogers and Davis, 1972, *op. cit.*

[35] S. H. Shamsuddin, *Field and Laboratory Studies of Fertilizer Runoff and Its Effect on Eutrophication of Natural Waters* (M.S. Thesis, Department of Agronomy, Louisiana State University, 1973), 79 p.

[36] C. E. Boyd, "Vascular Aquatic Plants for Mineral Nutrient Removal from Polluted Waters," *Econ. Botany* (Volume 24, 1970).

[37] *Ibid.* [38] Rogers and Davis, 1972, *op. cit.*

[39] Shamsuddin, 1973, *op. cit.*

[40] G. Webre, "Water Hyacinth - A Disposal Plant," *Dixie Magazine* (New Orleans: *The Times-Picayune*, March 2, 1975).

The implications of Wolverton's evidence of pesticide and heavy metal buildup in water hyacinths suggest that some attention should be paid to this process in the widespread blooms of hyacinth that exist in nature in the Atchafalaya Basin. To date, there are no useful chemical studies of this plant in its natural circumstances. Its ability to accumulate nutrient substances from waters flowing through the Atchafalaya Basin accounts in large part for its widespread occurrence and rapid growth rate. This ability may likewise account for its excessive production in areas of massive cover, which experience oxygen depletion mortalities of aquatic fauna.

Lynch *et al.* first reported that oxygen concentration beneath closed water hyacinth mats is very low.[41] Penfound and Earle reported values beneath closed mats with about 10.16 centimeters (cm), or 4 inches (in.), of bottom litter accumulation were less than 0.1 ppm, and beneath closed mats without significant litter accumulation, the values were about 0.5 ppm.[42] They also noted that in semi-closed mats (about 80% cover of water surface), the values averaged about 1.5 ppm.

These low values not only can be damaging to aquatic fauna, but amidst swamp forest trees, prolonged cover by water hyacinth mats and resulting restriction of gas exchange and direct exclusion of oxygen must also further depress oxygen levels in the root zone. This is additive to the stress of low oxygen brought about by standing water and sediment deposited over the roots. Thinning of tree stands in areas of chronic water hyacinth cover may be related to this. Seedlings, which normally might have appreciable flooding tolerance, may do less well in such low oxygen waters.

Flooding and Sedimentation Tolerances

The effects of flooding on the forest ecosystem are many and varied. Control is exerted on the composition of tree stands through inhibition of germination, mortalities to seedlings, and mortality or diminished competitiveness of larger trees.

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[41] J. J. Lynch, *et al.*, "Effects of Aquatic Weed Infestations on the Fish and Wildlife of the Gulf States " (U. S. Department of the Interior, Spec. Sci. Report, Volume 39, 1947).

[42] Penfound and Earle, 1948, *op. cit.*

Since no tree species of the area have seeds capable of germination beneath water, the presence of floodwater at a site during the normal germination time precludes the establishment of seedlings. For this reason, successful sets of cypress seed in the normal habitat of long hydroperiod are considered to be relatively infrequent events which occur only during drier years. Water tupelo, black willow, red maple, and cottonwood have seeds which germinate in late spring or summer, when it is much more likely that the soil will be dry over a wide area. Some cypress seed may also germinate at this time, although the optimum period is early spring. Most of the other species have seeds which germinate in early spring; consequently, there is little opportunity for germination except on the highest lands, which are not flooded at this time.

Seedling mortalities may occur if seedlings are completely covered by floodwaters for extended periods. Some species, especially baldcypress and tupelo gum, have a relatively high tolerance, although much depends on the oxygen content of water. Kennedy found that deep flooding (10 - 15 cm above the tallest seedlings) until June 1, July 1, and August 1, showed seedling survival rates of 93, 87, and 32%, respectively, in water tupelo seedlings 46 cm in height.[43] Seedlings not totally covered by floodwater showed excellent survival rates. Kennedy also simulated siltation by depositing sand about the flooded seedlings. He noted that it decreased survival by about 9% at a moderate depth of flooding (15 - 25 cm above groundline) and by about 33% for deeply flooded seedlings. It should be noted that silt and clay deposition may cause further decline in survival.

In a study of submergence tolerance of several bottomland hardwood species, Hosner ranked the following species in order from most to least tolerant: buttonbush, box elder, black willow, cottonwood, green ash, American elm, sycamore, red maple, sweet gum, and hackberry.[44]

Perhaps the most important selective effect of flooding is that due to mortality or reduced competitive ability of trees larger than seedling size. Broadfoot and Williston[45] cite the classification of

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[43] H. E. Kennedy, Jr., "Growth of Newly Planted Water Tupelo Seedlings after Flooding and Siltation," Forest Science (Volume 16, 1970).

[44] J. F. Hosner, "Relative Tolerance to Complete Inundation of Fourteen Bottomland Tree Species," Forest Science (Volume 6, 1960).

[45] W. M. Broadfoot and H. L. Williston, "Flooding Effects on Southern Forests," Journal of Forestry (September, 1973).

Hall, Penfound, and Hess[46] which was developed from observations of relative tolerance of trees flooded by reservoir construction. This is an artificial system and does not necessarily indicate tolerances to natural flooding cycles. According to their observations, some common trees of the Atchafalaya Basin fall into two categories: (1) moderately tolerant - box elder, river birch, water oak, American elm, and sycamore; (2) tolerant - red maple, persimmon, green ash, honeylocust, cup oak, cottonwood, water hickory, sandbar willow, water tupelo, and baldcypress. Broadfoot and Williston[47] noted that water tupelo was highly resistant to flooding in clear water, but easily damaged by muddy water.

Forest Types

Areas of long hydroperiod and low sedimentation rate are characterized by the cypress-tupelo association. This association was once very widespread over the basin, but increased sedimentation due to the growing discharge of the Atchafalaya River and the construction of the floodway have greatly diminished the area of the cypress-tupelo habitat. These areas were also strongly affected by the cypress logging industry. Following the virtual clear-cutting of the cypress stands, regeneration has been quite variable. Water tupelo, in most cases, has regenerated more successfully than cypress so that its representation in today's stands is greater than in those of the past. The cutting of the trees no doubt altered many other aspects of the community structure in substantial ways. The severe infestation of the forest tent caterpillar (*Malacosoma disstria*) on water tupelo, for instance, may be a result of the decline of some natural control agent in the altered community.

The change in the spatial structure characteristics of the cypress-water tupelo association must have substantially affected the water balance of the habitats. The interception of rainfall and transpiration from the virgin cypress forests were no doubt quite different than they are today. Hydroperiod and average depth of flooding have increased following cutting. The construction of the floodway and increased Atchafalaya discharge have also led to increases in flooding. These trends may partly account for the relatively greater success of water tupelo in the early stages of regenerative succession. The tent caterpillar is also a factor in such water-balance consideration and transpiration in the swamps.

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[46] T. F. Hall, *et al.*, "Water Level Relationships of Plants in the Tennessee Valley with Particular Reference to Malaria Control," *Journal of Tennessee Academy of Science* (Volume 21, 1946).

[47] Broadfoot and Williston, 1973, *op. cit.*

The sedimentation factor is critical in estimating the probable future of the cypress-water tupelo areas because neither cypress nor water tupelo seem to be able to survive rapid sedimentation. It is likely, therefore, that this association will continue to diminish in area within the floodway. It is possible to reduce the sedimentation resulting from the normal flooding of Atchafalaya River by either channelization or extended guide levees, but the substantial sediment contribution during times of floodway use will remain. Each time the floodways are used, a certain amount of area will become less suitable for the cypress-water tupelo association. The early stages of such change will be evident by increasing amounts of willow followed by other species.

Of all tree species in the Atchafalaya Floodway, the willows are best adapted to conditions of both flooding and sedimentation. This is evident from their widespread occurrence as dominants or important members in tree associations throughout the floodway. Their ability to withstand flooding and sedimentation seems to be related to the ready formation of both adventitious roots and aerenchyma tissue which allow for aeration of the root system in times of low oxygen stress. Willow is also a very prolific producer of wind-transported seed which is capable of rapidly spreading to any suitable site. Stands of willows also appear to undergo a self-thinning process which prevents stagnation in their generally rapid growth.

Cottonwood and sycamore are two other species that are adapted to withstanding high rates of sedimentation. Few other woody species have much tolerance, although there is a dependence here not only on the quantity of sedimentation, but also on the quality. Sedimentation by sandy sediment may be less damaging than that by fine sediment due to the differing porosity and permeability. This quality difference gives an important latitude to the sedimentation tolerance of the other hardwood trees characteristic of higher ground.

Sediment exerts its impact primarily through its effect on the root system. Since the increasing cover of the roots generally tends to lower oxygen available to them, it is probable that varying tolerances to sedimentation are largely related to adaptations allowing anaerobic respiration. Trees without such adaptation are quickly killed. Black willow, cottonwood, and sycamore have an additional important adaptation in their ability to form new root systems quickly which can replace the earlier ones. Green ash, pumpkin ash, and red maple also have some ability to form secondary roots.

The lands of lowest hydroperiod show peak diversity of all non-aquatic life forms. Trees include several species of oaks, few of which have significant tolerance to flooding. Lianas are numerous and important vegetational components. Understory and forest floor communities reach their highest diversity and standing crops in these forests. Wildlife food and cover conditions reach their optimal levels for the entire area with an abundance of mash, berries, and green forage.

A vegetation map of the Buffalo Cove area shows a typical distribution of forest types related to the bowl-shaped topographic character of that area. Willow, cottonwood, and bottomland hardwood occupy the high rim formed by natural overbank and spoil deposition. Away from the rim, willow and cottonwood become dominant due to more frequent flooding coupled with a lesser, but still significant, rate of sedimentation. The lowest, almost permanently flooded parts are occupied by cypress-tupelo, with willow invading as a result of sediment influx through openings connecting the basin with the surrounding channels, where velocities and sediment load are high (Figure 4-2).

Forestry Potential

The forestry value of the wetter bottomlands is a subject that has attracted relatively little attention since these areas were cut over for their virgin timber resources. This is partially due to the difficult operating conditions in swamplands. A commonly held opinion that such areas have inherently slow regenerative growth is not substantiated by fact. This view has probably arisen due to the many areas in which stands are stagnant from excessive density or which have been adversely affected by manmade drainage alterations. Virtually no skilled management practice has been applied to silviculture in a wet bottomland situation in this area. Some managed cottonwood plantings exist in higher terrain above U. S. Highway 190, but in the remainder of the area there has been little or no value placed on tree culture.

This attitude is still prevalent despite the fact that Hadley reported early in this century that water tupelo compared favorably with pines in pulpwood production potential.[48] Cypress has also been shown to have a high growth rate on sites in which hydroperiod is not overly prolonged.[49] In some cases at better-drained locations, one or two successive harvests have been made of cypress since the first cuttings. Many other trees characteristic of sites somewhat less wet than the cypress-tupelo zone are forms which should be of appreciable interest to the forest industry. Among these, green ash is possibly a highly desirable form for lands of lower hydroperiod and cottonwood for higher lands. Few of the other common trees of the lower-lying lands of the basin have been utilized significantly in the forest industry on a local scale although some are potentially useful. Willows,

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[48] E. W. Hadley, "A Preliminary Study of the Growth and Yield of Second-Growth Tupelo Gum in the Atchafalaya Basin of Southern Louisiana," The Lumber Trade Journal (November 15, 1926).

[49] J. R. Hims, Growth of Bottomland Forest Species in Southeastern Louisiana (M.S. Forestry Thesis, Louisiana State University, 1968), 83 p.

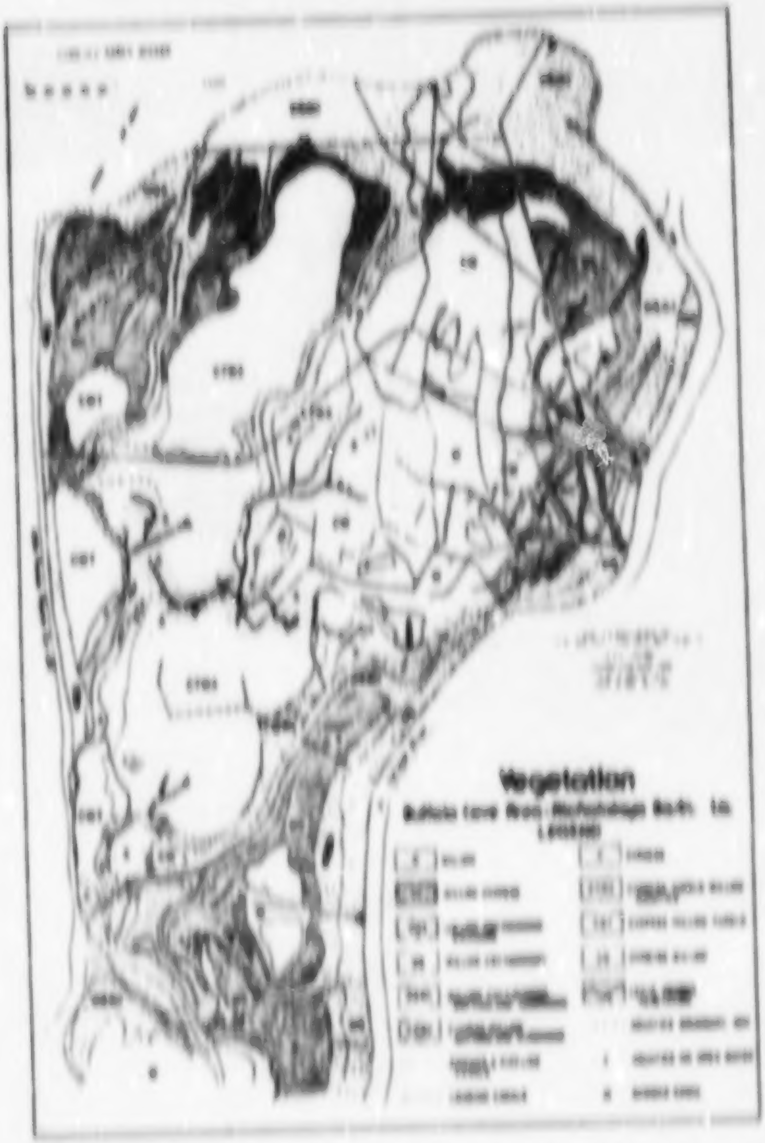

Figure 4-3. Distribution of forest types in the Buffalo Cove Management Unit.

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for instance, have been extensively utilized by industry in eastern Europe, particularly for pulp. If this practice were to appear in this area, black willow could become an important forestry species in the basin where it is so widespread because of its high sedimentation and flooding tolerance. A potential for utilization other than pulp also exists. On some of the better-drained sites, black willow can reach timber log size, and its wood is highly desirable for several reasons.

Tupelo gum does not presently attain maximum growth rates due to the heavy defoliation which typically occurs on them as a result of caterpillars of the species *Malacosoma disstria*. In Alabama, U. S. Forest Service workers found that over a period of five years, growth was 50% greater (in diameter at breast height) for uninfected plots.[50]

The various oaks are desirable not only for wood, but for their mast production, which is essential for a variety of wildlife species. Careful attention should be given in planning of the floodway in order to provide adequate amounts of mast-producing hardwood forest. The appropriate locales for this are areas of least frequent flooding and lowest siltation rates. The water oak, overcup oak, and Nuttall oak are the best-adapted forms for survival on such locations within the floodway.

An important strategy for management of lower bottomland forests is that of water-level manipulation. This can be used for various purposes, such as optimization of growth of a particular species or elimination of competitor species. Water-level manipulation can also be an aid to harvesting through flotation logging.

Water-level manipulation can be used not only as a forestry strategy, but also for other purposes. Timely regulation of water level may be incorporated as an aspect of water hyacinth-control programs to provide for a larger amount of dessication and oxidation of organic materials. Obviously, control of water can be used in crawfish culture or in regulating habitat conditions for certain waterfowl species. With careful attention, management practices can consider all needs simultaneously.

The exact manner by which water-level regulation can be used will be determined by the morphological and hydrological character of a given site. Low dikes can be used to catch and hold water at times of high water for storage over a period of lower stage. Different areas can be dewatered at various times depending on the requirements of the particular species being managed. The overall design should aim at energy economy by using gravity as much as possible for movement of water.

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[50] R. C. Morris, personal communication (Stoneville, Mississippi, February, 1975).

Not only must water be allocated according to the needs and requirements of various species, but sediment must also be similarly allocated. For instance, areas managed for willow pulpwood production can be used as sediment traps from which clearer water can be transferred to areas managed for species not as tolerant to sedimentation as willow. Gradual filling will lead to a need for rotation of use of such areas.

Numerous innovative developments in forestry product utilization are likely to further increase the value of forested areas, such as the Atchafalaya Basin. Short rotation forestry, for instance, is a method for production of young coppice-regenerated trees for fiber production. Sycamore is a basin species which has been investigated for short rotation culture, and it appears that its attributes of rapid initial growth and good pulping qualities at four years of age are favorable to this technique.[51] Other species which regenerate well by sprouts and which have relatively rapid early growth and good pulping qualities are also suitable for this type of culture. Of the trees typical of the basin, cottonwood, red maple, sweet gum, and possibly the willows are suitable on various types of sites.

Utilization of the complete tree is an innovation which has been receiving increased attention. In a review of this subject, Keays sums it up by saying, "The tops should be used for pulp; branches for pulp, chemicals or fuel; foliage as a source of chemicals, and everything remaining for conversion to heat, power, and chemicals."[52] This touches on another area of promising innovation, that of the growing silvichemical industry which offers much hope of increasing efficiency of forest yields of useful materials. The future of this already-growing industry has been appraised recently by Goheen in a review which lists numerous potential products that will contribute to energy, food, and chemical raw material supplies.[53]

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[51] Klaus Steinbeck, Short Rotation Forestry in the United States: A Review (American Institute of Chemical Engineers, Symposium Series, Volume 70, 1974).

[52] J. L. Keays, Complete-Tree Utilization of Mature Trees (American Institute of Chemical Engineers, Symposium Series, Volume 70, 1974) 75 p.

[53] D. W. Goheen, Silvichemicals - What Future? (American Institute of Chemical Engineers, Symposium Series, Volume 69, 1973).

V
FISH AND WILDLIFE RESOURCES

The Atchafalaya Basin is well known by sport fishermen in the State of Louisiana, and the basin ranks high among commercial freshwater fish production areas in the United States. Game fish species in the basin include largemouth bass, bluegill, warmouth, and other species. Several factors, acting both individually and in combination, create almost ideal conditions for fish populations in the basin and maintain high annual fish production.

In addition to its immense fishery resources, the Atchafalaya Basin is also home to numerous species of waterfowl and terrestrial or semi-terrestrial species of wildlife. It is not surprising in a water-dominated system such as the Atchafalaya Basin that many of the animal species there are dependent, to a greater or lesser extent, on the prevalent wet conditions for their well-being and livelihood. Indeed, nearly all animal habitats in the basin, including the relatively high natural levee ridges, can be classified as a wetland of one type or another.[54] Since water is as necessary as the presence of nutrient minerals for organic production, it is perhaps this overall wet character of the basin which accounts for, more than any other factor, its high productivity.

Factors Enhancing Fish Production

Perhaps the most important feature affecting fish production in the basin is the annual fluctuation in water levels and area covered by water. Each spring, associated with high stages on the Atchafalaya River, low-lying swamps and floodplain areas are filled with water. At highest river stages, much of the area inside the floodway is essentially one vast shallow lake. The area of aquatic habitat is greatly increased. Newly flooded areas provide food for both fishes and fish food organisms in the form of flooded terrestrial plants and animals.

Nutrients brought in by river floodwaters and derived from flooded areas increase the fertility of basin waters, spurring the growth of phytoplankton and other aquatic plants. Phytoplankton can be utilized directly by certain fishes (e.g., shad) or form the base of a food chain leading to predacious fishes. Zooplankters which feed on phytoplankton are important foods for larval and small adult fishes.

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[54] U.S. Department of the Interior, Fish and Wildlife Service, Wetlands of the United States (Circular No. 39, Washington: U.S. Government Printing Office, 1956).

Organic detritus, including dead leaves, stems, bark, and other material of animal origin produced by in situ processes, as well as imported detrital material brought in by river currents, also functions as a food-web base. Detrital material is consumed directly by crawfish, and the short detritus-crawfish-fish food chain is a major reason for the high fish production of basin waters.[55]

Spring floods coincide with the period of fish reproduction and can induce spawning of certain species. Fish reproduction thus occurs at a time when foods for young fishes are readily available. Buffalo fish are influenced by floodwaters in their spawning activities and often move into shallow, previously unflooded areas to spawn. Spawning migrations of such fishes as shad, freshwater drum, and gars are also influenced by rising water. Lantz attributed the failure of largemouth bass to spawn in certain Louisiana impoundments to the presence of a "repressive factor," or substance, secreted into the water by the fish.[56] Floodwaters in areas such as the Atchafalaya Basin effectively dilute the repressive substance, resulting in good spawns by largemouth bass and perhaps other sport fishes.

Besides the benefits of flooding of swamps and floodplain in the spring, the drainage and partial or total dewatering of these areas in the summer and fall periods provide additional benefits to fish populations. Exposure of the swamp floor to the atmosphere allows rapid aerobic decomposition of accumulated muck and debris and permits the growth of terrestrial plants which will serve as a food source for fishes or fish food organisms when the area is again reflooded. Dewatering of swamps concentrates fish populations into lakes and bayous where smaller forage species, such as shad and young sunfishes, may be efficiently preyed upon by larger predators.[57] Drainage of swamps and backwater areas in the summer and fall is necessary for good crawfish production in the following spring. Crawfish are important fish-food organisms in basin waters.

In general, the abundance of various fish-food organisms in the basin is also a factor favorable to fish populations. Abundant planktonic organisms, such as copepods and cladocerans, furnish food for larval and juvenile game and commercial fishes as well as for the adults of small forage fishes. Various insect larvae, worms, snails, clams, amphipods, isopods, and freshwater shrimp furnish food for forage fishes, which in turn are fed upon by more predacious game species. Tremendous numbers of crawfish in the spring provide a vast food source for many fish species. Lambou and Lantz have pointed out the importance of crawfish as a fish-food organism in the basin.[58,59] Bryan *et al.* found crawfish in [illegible] out of 14 fish species which were examined for stomach content.[60] Crawfishes also serve as food for a variety of other animals, including aquatic and terrestrial forms.

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[55] Victor Lambou, U.S. Environmental Protection Agency, personal communication.

[56] Kenneth Lantz, "Natural and Controlled Water Level Fluctuations in a Backwater Lake and Three Louisiana Impoundments" (Louisiana Wild Life and Fisheries Fish Division Bulletin No. 11, Louisiana Wild Life and Fisheries Commission, Baton Rouge, Louisiana, 1974), 36 p.

[57] *Ibid.*

Predacious freshwater fishes in the basin may benefit from the migration of certain marine fishes and blue crabs into the area. Striped mullet, particularly, are abundant and widespread in basin waters. Crabs and mullet are undoubtedly eaten by gars, largemouth bass, and other predators.

The major requirement, then, for maintaining the present value of the fishery resource is maintenance of, insofar as possible, those conditions which support the resource. Drainage of backwater swamps and lakes is clearly at odds with fish production; aquatic habitats must necessarily be preserved. Fish populations in the Atchafalaya Basin are adapted to annual water-level fluctuations and are dependent on them for high productivity. Thus, the present fluctuating water-level characteristics must be maintained or the value of the resource will be decreased.

Factors Enhancing Crawfish Production

The two commercial crawfishes of the Atchafalaya Basin are considered together in this report. Differences in mating and spawning seasons, foods, and microhabitats undoubtedly occur between the two species, but have been little studied. The crawfish has been the most valuable commercial species harvested in basin waters in the past seven years. It also serves important ecological functions. Crawfish feed on small worms and insect larvae living in the bottom mud and on living aquatic and submerged terrestrial plants and plant detritus.

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[58] V. W. Lambou, "Utilization of Macrocrustaceans for Food by Freshwater Fishes in Louisiana and Its Effect on the Determination of Predator-Prey Relations" (Volume [illegible], No. 1 *Progressive Fish Culturist*, 1961).

[59] Lantz, 1974, *op. cit.*

[60] Bryan *et al.*, 1974, *op. cit.*

In general, the water requirements for crawfish are well known. Crawfishermen are often able to predict the relative abundance of crawfish before a given season by noting water levels in the swamp. If water in the swamp begins rising in the late fall (by November), and if a high water level is maintained through the winter period, then there is generally a good harvest of crawfish during the following spring. Low water levels during the late fall and winter generally forbode a poor crawfish season. If water levels remain high, however, beyond the usual crawfish season (the bulk of the harvest is in by the end of June) and into the summer months, then the next year's harvest is low. A pronounced drop in water levels during the summer and early fall, so that much of the swamp floor is exposed, is necessary for a good harvest during the following season. Crawfish are adapted to alternating wet and dry conditions, and it is probably the annual cycle of flooding and draining over a large area that is responsible for the high production of crawfish in the Atchafalaya Basin.

Water levels are closely linked to the life cycle of crawfish. In general, the rising and high water periods in the late winter and spring are the periods during which growth and maturity of young crawfish occur. The latter part of this period is when most crawfish harvest takes place. Mating of crawfish occurs "whenever mature males (form I) and females come together in shallow warm water."[61] Although it is likely that some mating activity occurs on an almost year-round basis in the basin (excluding the coldest months), most mating probably begins in May and June and continues through the summer during the falling and low water periods. In the summer, in response to low water levels, crawfish burrow into the bottom mud. Burrowing may also be to some degree a post-mating response, since some crawfish in farm ponds begin to burrow after the peak of the mating period before water levels have dropped appreciably.[62] However, when water levels in the swamp remain high through the summer, many crawfish do not burrow and thus remain exposed to aquatic predators.

Egg-laying begins about two months after mating and occurs mostly during the summer low-water period from about June through September. The eggs are held by a sticky substance (glair) on the abdominal appendages of the female. Eggs hatch after two to three weeks, depending on temperature, and the hatching period extends from about July through October. Both egg-laying and hatching can occur while the females are still in burrows, but at some time during this period the females will leave the burrows, often after a rainfall, and move to rainpools or other flooded areas. The young crawfish cling by their claws to the swimmerets of the female where they undergo at least two molts. After the second molt (5 days after hatching), they are ready for an independent existence, but they may remain attached to the female for a longer time.

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[61] George H. Penn, Jr., "A Study of the Life History of the Louisiana Red-Crawfish, Cambarus Clarkii Girard" (Ecology, Volume 24, No. 1, 1970).

[62] Cecil LaCaze, "Crawfish Farming" (Louisiana Wild Life and Fisheries Bulletin No. 7, Louisiana Wild Life and Fisheries Commission, Baton Rouge, Louisiana, 1970), 27 p.

The critical period in the crawfish life cycle occurs when young crawfish leave the female to go foraging on their own. Lack of water in the basin at this time is a severely limiting factor on crawfish production. Heavy autumn rains are beneficial to the young crawfish because they provide aquatic habitats which are free from predator fishes. However, if rain does not come, many young crawfish probably die from lack of aquatic habitat.

Best crawfish years are usually those when the river has begun its annual rise during the late fall or early winter of the previous year and remains high throughout the spring season. Similarly, poor crawfish years usually occur when the river does not begin to steadily rise until February or March of the same year, or when river stages were high through the summer of the previous year. Due to poor data, no precise relationship can be established between early river rises and increased crawfish harvests. A direct relationship seems probable, however, because of the necessity of aquatic habitats for young crawfish during the fall of the year. The best crawfish production year on record (1973) was caused not only by the abundance of water during the spring of that year due to the opening of the Morganza Floodway, but also by the high stages of the Atchafalaya River,which caused flooding of backwater areas as early as October of 1972.

Backwater flooding of swamps in the fall of the year also introduces predator fishes which consume a great number of young crawfish. Losses due to predation by fishes and other predators are probably not as great, however, as losses incurred by a lack of water in the fall of the year. Many crawfish may be able to find escape cover amongst flooded vegetation. It is possible that the deliberate introduction of river water to allow for flooding of backwater areas by around the first of November (in years when this does not occur naturally) would be beneficial to crawfish production.

Requirements for maintaining high crawfish production in the basin are 1) maintenance of the large area of aquatic habitat, 2) continuation of annual water-level fluctuations, and 3) elimination of high water levels during the summer and early fall. Additionally, earlier fall flooding in some years may be beneficial to crawfish production.

While overbank flow of the Atchafalaya River is a major contributor to the high productivity of the Atchafalaya Basin, it is also a major contributor to the eventual elimination of many of the aquatic habitats in the basin. Each overflow of the river introduces sediment into swamps, lakes, and over the flood plain. Sedimentation in the Buffalo Cove area is estimated to have occurred at a rate of about 0.03m (0.1ft)/year over the past 40 years (Figure 3-2). As this process of sedimentation occurs year after year, the end result is the elevation of the floodway floor. The Corps of Engineers has estimated that the average thickness of the sediment fill between the east and west protection levees and south of the end of the Atchafalaya River guide levees over the 10-year period prior to 1950 is about .99m (3.3ft).[63] A comparison of the diagrams of the Grand Lake area through the period 1917 to 1972 shows in a striking manner the filling in with sediment of this once vast lake area.[64] It should be pointed out that the lowest places, such as lakes, are the first to fill. Although increasing amounts of sediment are now being transported through the middle basin and being deposited in the emerging delta of the river in Atchafalaya Bay, it can be expected that sedimentation in the middle basin in such areas as Grand Lake, Six Mile Lake, Flat Lake, and in other areas will continue to occur.

Sediment materials, then, fill in aquatic habitats in the basin, making them progressively shallower. Certain tree species (baldcypress, tupelo-gum) are not tolerant of sedimentation deposited over their roots and gradually become replaced by more sediment-tolerant species as cottonwood, willow, and sycamore. Changes such as this among the dominant species of a community probably have far-reaching effects on other members of the community.

Seemingly, then, those processes which the Corps of Engineers desires to stop (overbank flow in the Atchafalaya River and resultant sedimentation) are not completely incompatible with long-term maintenance of the natural features of the basin which can hopefully be preserved. Overbank flow is needed to maintain the productivity of aquatic resources, but the sediment is not needed, and indeed, is detrimental to the long-term viability of the system. The overall requirements, then, for maintaining the value of the fishery resources are:

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[63] U.S. Army Corps of Engineers, *Flood Control, Mississippi River and Tributaries, Atchafalaya Basin Floodway, Louisiana* (General Design Memorandum, Prepared in the Office of the District Engineer, U.S. Army Engineer District, New Orleans, Louisiana, 1963).

[64] Coastal Environments, Inc., 1974a, *op. cit.*

1) a continuation of the annual watering and dewatering sequence, and

2) a minimization of the amount of sediment leaving the Main Channel and larger distributaries.

Since sediment is carried by river water, it will be necessary to control the amount of river water entering backwater swamps and lakes in order to limit the amount of sediment entering those areas.

Waterfowl

The Atchafalaya Basin is located near the southern terminus of the Mississippi Flyway, which is utilized by some 8.5 million waterfowl, or approximately 30% of the continental waterfowl population.[65] Major species of ducks occurring in the basin include the following:

Puddle Ducks	Diving Ducks	Mergansers
Mallard	Ring-necked duck	Hooded merganser
Gadwall	Canvasback	Common merganser
Pintail	Lesser scaup	Red-breasted merganser
Blue-winged teal		
Green-winged teal		
American wigeon		
Shoveler		
Wood duck		

There are three general habitat types for waterfowl within the Atchafalaya Basin: the coastal marshes, open-water lakes and streams, and forested wetlands.[66] All of the ducks listed above utilize the coastal marshes. However, of the three types of ducks, the puddle ducks, particularly wood ducks and mallards, are frequently found in the freshwater lakes, streams, and swamps. The wood duck is a year-round resident nesting in the swamps of the Atchafalaya Basin. Diving ducks are usually most numerous in more saline habitats, such as brackish water lagoons and bays. A relatively few diving ducks do, however, occur in the freshwater habitats of the middle and northern basin each year. The lower Grand Lake and Six Mile Lake area, in the vicinity of Tiger Island, is intensively utilized as a wintering area by 300-500 canvasbacks during the winter. Canvasbacks, "the most famous and the most highly esteemed of our ducks,"[67] have in recent years been declining in numbers as a result of the cumulative loss of both nesting and wintering habitat.[68]

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[65] U.S. Department of the Interior, 1974, *op. cit.*

[66] Hugh A. Bateman, *Needs and Goals of the Atchafalaya Basin Swamp* (Atchafalaya Basin Management Study, Baton Rouge, Louisiana, 1973), 27 p.

Of the mergansers, only the hooded merganser is regularly found in the wooded portions of the Atchafalaya Basin. A few hooded mergansers may nest in the basin in the summer.

Besides ducks, the Atchafalaya Basin is utilized by thousands of coots each winter. A significant number of blue/snow geese winter in the coastal marshes of western Terrebonne Parish in the vicinity of Lost Lake and Pointe au Fer Island.

Bateman states that the value of the Atchafalaya Basin to waterfowl "can be measured in two important respects: 1) as a large, high-quality wintering ground for migratory waterfowl, and 2) as one of the largest units of quality wood duck production habitat remaining in the United States."[69]

The general requirement for maintaining waterfowl values is obvious: the Atchafalaya Basin must remain a wet or seasonally flooded area or it will lose its attractiveness to waterfowl. Any flood control project which would cut off water to backwater swamps and lakes would destroy waterfowl habitats. More particularly, the present natural pattern of water level fluctuations must be maintained or the value of the basin to waterfowl will be reduced. The current sequence of low water levels in the late summer and fall followed by high water levels in the winter and spring allows for the growth of important waterfowl food plants during the low-water period and for their utilization by waterfowl during the high-water period. The control of water levels for the increased production of waterfowl food plants is an established practice in waterfowl habitat management.

Other problems and needs related to waterfowl in the Atchafalaya Basin discussed by Bateman concern time of fall flooding, water hyacinth coverage, siltation, and provision of waterfowl refuges to attract and hold birds.[70]

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[67] Francis H. Kortright, *The Ducks, Geese and Swans of North America* (Wildlife Management Institute, Washington, D.C., 1942)

[68] U.S. Department of the Interior, 1974, *op. cit.*

[69] Bateman, 1973, *op. cit.*

[70] *Ibid.*

During some years and in some areas of the basin, due to either inadequate autumn rainfall or to delayed stage increases in the Atchafalaya River, or both, a lack of water in October and November causes migratory waterfowl to avoid this area in favor of wetter locations. Bateman suggests that a controlled manipulation of swamp and backwater lake water levels "that would allow a gradual rise, 2 to 4 inches a week, beginning about two weeks prior to the open hunting season, would greatly benefit waterfowl use and hunting."[71] It should be pointed out, however, that it would be difficult to introduce river water into backwater swamps and lakes during the periods when the river is falling or at low stage. The only way this could be practically accomplished at present is by increasing the river stage to allow more Mississippi River water to enter the floodway through the Old River control structure. This is not, however, a new idea. The Louisiana Wild Life and Fisheries Commission has recommended for many years that the Old River control structure be operated as a variable control structure for fish and wildlife management purposes.[72] Bateman's suggestion for earlier fall flooding during some years to benefit waterfowl use is consistent with recommendations made elsewhere in this report for earlier fall flooding to benefit crawfish production.

Water hyacinths are of little or no value to waterfowl. On the contrary, they are poor waterfowl food plants which may grow so thickly as to eliminate much open-water habitat and make access to hunting areas difficult. Water hyacinth control in the basin is not an easy task. Most spraying efforts (with the herbicide 2, 4, D) are directed towards keeping waterways navigable. The pest plant has thus proliferated in backswamp areas away from channels where spray boats do not have access. No feasible method of herbicide application to backswamp areas is now available. Cold winters kill back water hyacinths rather severely, depending upon the duration of temperatures below freezing. The ability of the swamp waters to hold heat is, however, considerable. This phenomenon tends to protect water hyacinths from cold temperatures.

The Louisiana Wild Life and Fisheries Commission has recently experimented in the biological control of water hyacinths with the introduction of an apparently host-specific South American weevil (*Neochetina* sp.) into several experimental areas. The larva and adult of the weevil feed on the leaves of the water hyacinth plant. It is not thought that control will be accomplished by the direct feeding activities of the weevil, but that the scars and injuries to the plant tissue caused by the feeding activities will render the water hyacinth plant more susceptible to plant diseases caused by rusts or other organisms. At the present time, there is little data available on the introduction or effects of the weevil, but there has been some spread of the weevils to areas outside of the immediate introduction sites.[73]

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[71] *Ibid.*

[72] *Ibid.*

Sediment deposition in the Atchafalaya Floodway is a major problem that is discussed at length in other sections of this report. Siltation in the floodway has over the years eliminated much open water habitat for waterfowl and has made hunter access to waterfowl areas difficult. Certain areas in the floodway (Duck Lake) have sufficiently clear waters to allow the growth of submerged aquatic plants, such as water celery (*Vallisneria* sp.), which are important waterfowl food plants. Encroachment of highly sediment-charged waters into these areas will create conditions unfavorable to the growth of these plants.

Bateman cites a need for waterfowl refuges in the Atchafalaya Floodway.[74] Most of the land in the floodway is privately owned, and a large area is leased for hunting purposes to private hunting clubs. The State of Louisiana does own some land within the floodway which may be suitable for the establishment of a waterfowl refuge. However, for greatest waterfowl benefit, refuges should be established in different habitat types (e.g., cypress-tupelo swamp areas, open water bodies, main river channel areas). Bateman recommends the establishment of "at least 4 small (1,000 acre) refuges (or rest areas)... somewhere in the basin."[75] Refuges for waterfowl (where hunting is not allowed in the open season) greatly benefit hunting in areas outside of the refuges because more birds are attracted to the area, and their residence time is increased.

Furbearers

Furbearers in the Atchafalaya Basin include nutria, raccoons, mink, otters, opossums, muskrats, striped skunks, beavers, bobcats, coyotes, and foxes. The alligator is classified as a furbearer in Louisiana, but it is not currently exploited in the basin. Nutria, mink, and raccoons comprise a large portion of the total reported catch and value in the upper and middle basins,[76] while nutria, muskrats, and raccoons are probably the most important furbearers in the marsh area of the lower basin. A few otters are caught in both areas each season. Opossums are taken in significant numbers in spite of the low value of their pelts. The American beaver has only recently extended its range into the Atchafalaya Basin. Its pelt currently has a low market value, and few beavers are trapped. Skunks, bobcats, foxes, and coyotes are taken in insignificant numbers or not at all.

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[73] Don Lee, personal communication.

[74] Bateman, 1973, *op. cit.*

[75] *Ibid.*

The greatest value of the basin as a fur-producing area is in the production of mink and raccoon pelts. Approximately 34% and 25%, respectively, of the mink and raccoon pelts harvested in Louisiana during the 1971-72 trapping season came out of the natural Atchafalaya Basin. Although more nutria are caught in the area (as well as state-wide) than any other furbearer, nutria production is low when compared to state-wide figures.[77]

Besides their pelt value, the carcasses of nutria, raccoons, and opossums are sold either for pet or caged mink food or human consumption. Food, habitats, and other pertinent information concerning the major furbearers in the basin are discussed below.

Nutria (*Myocastor coypus*)

The nutria has in the 37 years since its introduction come to be the most valuable furbearer in the state on the basis of numbers of pelts taken per year and overall value of pelts. Nutria live in marsh and swamp areas and may also be numerous near drainage ditches, ponds, and lakes in more upland areas. They are herbivores which feed on a large variety of plants including maidencane, wiregrass, three-cornered sedge, bulltongue, alligatorweed, pondweeds, pickerelweed, duckweed, and other plants. Water hyacinths are also eaten by nutria, but not enough to control the pest plant as once was hoped. They may sometimes invade sugarcane or rice fields where they do great damage.

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[76] J. D. Nichols, *A Survey of Furbearer Resources in the Atchafalaya River Basin, Louisiana* (Unpublished Master's Thesis, Louisiana State University, Baton Rouge, Louisiana, 1973), 104 p.

[77] *Ibid.*

Nutria occur in both marsh and swamp habitats in the Atchafalaya Basin. Both freshwater and brackish marshes are utilized by the nutria, but the center of their abundance is probably in the freshwater marshes where there exists the greatest variety of preferred food plants. All of the forested wetlands in the Atchafalaya Floodway furnish habitats for nutria. In the upper and middle basin, cypress-tupelo swamps, according to Nichols, are preferred trapping areas not only for nutria, but for other types of furbearers as well.[78]

Raccoon (Procyon lotor)

As has been mentioned, approximately one-fourth of the raccoon pelts harvested in the State of Louisiana during the 1971-72 trapping season were taken from the natural Atchafalaya Basin,[79] and a similar percentage is probably taken on an annual basis. They occur throughout the Atchafalaya Basin in marsh, swamp, and bottomland hardwood areas. Raccoons in the coastal marshes (*Procyon lotor megalodous*) have a more yellowish color[80] and a lower pelt-value[81] than the swamp and woods-dwelling raccoons (*Procyon lotor varius*) which occur throughout the rest of the state.

Foods eaten by raccoons include crawfish, crabs, snails, clams, insects, acorns, blackberries, grapes, and other items of both animal and vegetable nature.[82,83] They are known to prey on alligator eggs and young in the coastal marshes.[84]

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[78] *Ibid.*

[79] *Ibid.*

[80] George H. Lowery, Jr., *The Mammals of Louisiana and Its Adjacent Waters* (Published for the Louisiana Wild Life and Fisheries Commission by the Louisiana State University Press, Baton Rouge, Volume 24, 1974a), 565 p.

[81] A. W. Palmisano, *Commercial Wildlife Work Unit Report to Fish and Wildlife Study of the Louisiana Coast at the Atchafalaya Basin*, Volume I (1971).

[82] Lowery, 1974a, *op. cit.*

[83] Nichols, 1973, *op. cit.*

[84] Ted Joanen, *Nesting Ecology of Alligators in Louisiana* (Proceedings of the 23rd Annual Conference of the Southeastern Association of Game and Fisheries Commission, 1969).

Mink (*Mustela vison*)

Although the coastal marshes produce an abundance of mink pelts annually, the more inland swamps and bottomland hardwood areas in the state probably contain higher populations of this animal. St. James Parish, on the Mississippi River, produces from 10 to 14 thousand mink annually.[85] During the 1971-72 trapping season, approximately 34% of the mink harvested in the state came out of the Atchafalaya Basin.[86] "The abundance of the species in the bottomland swamps has been attributed to the presence of crayfish, one of its main items of food in these areas."[87]

Minks are carnivorous, feeding on aquatic animals such as crawfish, crabs, fish, and frogs, and terrestrial species such as rats, mice, and rabbits. In the marsh, mink are major predators on muskrats.

Otter (*Lutra canadensis*)

Otters are the most valuable furbearers in Louisiana based on the value of single pelts. The average price paid for these pelts since 1940 has been $[illegible].74, with a high price of $42.00 being paid during the 1972-73 season.[88] Otter pelts are thick, lustrous, and very durable.

Otters are inhabitants of wetland areas, including marshes and swamps. Palmisano states that the average catch of otters in the marsh is less than one otter per 2,000 acres and that the most productive marshes are fresh to brackish types.[89] Swamp areas in the state are not as intensively trapped as the coastal marshes, and statistics on the harvest of the various types of furbearers from different habitat types or geographic areas are almost non-existent except for a few state-owned lands. No direct comparison can be made, therefore, on the abundance of otters in swamp and marsh habitats on the basis of trapping records. Swamps, however, are perhaps somewhat better habitats for otters than the coastal marshes because of the greater abundance of den sites around tree bases and the somewhat greater food availability in the form of crawfish.[90]

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[85] Lowery, 1974a, *op. cit.*

[86] Nichols, 1973, *op. cit.*

[87] Lowery, 1974a, *op. cit.*

[88] *Ibid.*

[89] Palmisano, 1971, *op. cit.*

Otters are carnivores, feeding on fish, frogs, turtles, snakes, crawfish, and crabs. Terrestrial animals, such as small rodents, are occasionally taken.[91] Because of their fish-eating habits, otters sometimes swim into hoop nets set by commercial fishermen, where they drown.

Opossum (Didelphis virginiana)

Opossums occur throughout Louisiana in wooded areas, marshes, cleared fields, and in the vicinity of human habitations. They are abundant in the Atchafalaya Basin. Opossum pelts have a low value, and probably many more opossums are taken by trappers than those whose pelts are actually prepared for the market. Their flesh is valued at about $0.50 per pound.

Opossums consume insects, earthworms, crawfish, carrion, acorns, wild grapes, blackberries and other fruits.[92] Around houses, they frequently turn over garbage cans in search of food. The omnivorous habits of opossums are one reason for their great success and abundance.

Muskrat (Ondatra zibethicus)

The muskrat has long been and continues to be one of the mainstays of the Louisiana fur industry. Although its importance has been somewhat overshadowed by that of the nutria in recent years, good catches of muskrats are still made in the coastal marshes on a year-to-year basis.

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[90] Nichols, 1973, op. cit.

[91] Lowery, 1974a, op. cit.

[92] Nichols, 1973, op. cit.

In the Atchafalaya Basin, muskrats occupy both swamp and marsh habitats. They are much more abundant in marsh habitats, however, for a variety of reasons. O'Neil and Palmisano have established that muskrats' preferred habitat in Louisiana is in the brackish-water marshes occurring in the coastal zone.[93,94] The climax vegetation in this type of marsh is dominated by wiregrass (Spartina patens). Muskrat abundance in brackish-water marshes is, however, closely linked to the abundance of the sub-climax plant, three-cornered sedge (Scirpus olneyi). Whenever a wiregrass marsh is disturbed by fire or by temporary saline-water inundation, three-cornered sedge comes in temporarily until the climax plant, wiregrass, recovers and chokes it out. During this period, muskrats increase greatly in abundance and, for proper marsh management, must be removed by trapping, or severe "eat-outs" (where muskrats completely consume the existing vegetation including root systems, resulting in the break-up of marsh soils) will occur. Muskrat eat-outs, depending on their severity, take from one to several years to be revegetated, during which time the value of the area is greatly reduced for muskrats as well as other inhabitants of the marsh.

In the Lower Atchafalaya Basin, however, marshes are predominantly freshwater in character because of the heavy dilution effect of Atchafalaya River discharge. Although muskrats occur in freshwater marshes, they never reach high population levels as in brackish water marshes.

Muskrats are found in swamp habitats in low numbers as compared to brackish marshes. In these areas, muskrats do not build houses as they do in the marsh, but construct bank dens or occupy burrows dug by other animals. Swamp habitats, especially those in the Atchafalaya Floodway, are generally subject to rather high changes in water levels. Spring flooding of swamps in the Atchafalaya Basin probably causes some loss of nest young due to drowning. In addition, high quality muskrat food plants are not abundant in swamp habitats.

Food habits of muskrats vary according to the type of habitat they occupy. In freshwater marshes, they eat maidencane, cattails, roseau cane, Sagittaria spp., sedges, and some animal matter. In

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[93] Ted O'Neil, The Muskrat in the Louisiana Coastal Marshes (Federal Aid Section, Fish and Game Division, Louisiana Department of Wild Life and Fisheries, New Orleans, Louisiana, 1949), 152 p.

[94] Palmisano, 1971, op. cit.

swamps, muskrats eat *Sagittaria* spp., pickerelweed, lizard's tail, alligatorweed, and other plants. In freshwater areas, they feed somewhat more heavily on animal materials than they do in brackish water areas. Animals eaten include fishes, crawfishes, crabs, and mussels.[95,96]

Furbearer Requirements

The main requirement for the continued abundance and well-being of furbearers is the preservation of the various wetland environments as they presently exist. Most of the furbearers in the basin are traditionally associated with, and are actually most numerous in, wetland environments. If a single reason for the fitness of the basin environments to support fur-bearing mammals can be pointed out, it is the overall wet character of the forest and grassland habitats in the basin, which is most important and which should be preserved.

Game Species of Wildlife

Major game species in the basin are deer, squirrels, rabbits, woodcock, and doves. These species are frequently hunted. Other game animals present include turkeys, bears, quail, foxes, raccoons, opossums, bobcats, snipe, and rails. These last-named species are infrequently hunted due to low population numbers or to a lack of hunter interest.

White-tailed Deer (*Odocoileus virginianus*)

White-tailed deer occur throughout the Atchafalaya Basin, including swamp and marsh areas. Highest populations, however, are found in better-drained areas in the upper basin, where the population density is estimated at one deer per 20-30 forest acres.[97] This density must approach the carrying capacity of the range.[98]

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[95] O'Neil, 1949, *op. cit.*

[96] Lowery, 1974, *op. cit.*

[97] Needs and Goals Sub-Committee, Atchafalaya Basin Management Study, *Needs and Goals of the Atchafalaya Basin Swamp* (Atchafalaya Basin Management Study, Baton Rouge, Louisiana, 1973), 27 p.

[98] Dr. Lyle S. St. Amant, *Louisiana Wildlife Inventory and Management Plan* (Louisiana Wild Life and Fisheries Commission, New Orleans, Louisiana, 1959), 329 p.

The upper basin area is forested with bottomland hardwood species such as water oak, Nuttall oak, sweet gum, red maple, bitter pecan, willow, cypress, and tupelo gum. Many of the larger cypress and tupelo gum trees in the upper basin are remnants of swamps which occurred in this area prior to construction of guide levees on the Upper Atchafalaya River. Guide levee construction deprived these swamps of much of their water source, resulting in partial drainage of the swamp area and allowing the growth of competitive species more suited to drier sites. Vegetative and water-level changes have increased the value of the area as a habitat for deer.

Food conditions for deer in the present bottomland hardwood areas are excellent. Items reported as deer foods in alluvial bottomlands and which are abundant in the upper basin are buds, leaves and twigs of young trees such as cypress, sweet gum, various oaks, red maple, ash, and bitter pecan, shrubs such as buttonbush, and vines such as greenbriar and rattan vine.[99] Acorns and other mast, eaten by deer in the fall, are abundant in the upper basin.

In the middle basin (in general, that area of the natural Atchafalaya Basin between Interstate Highway 10 and Morgan City), elevations are lower and backwater areas are subject to seasonal and prolonged flooding, the population density of deer is estimated at one deer per 50-60 acres.[100] Deer in this area make much use of low, natural levee ridges and spoil banks which constitute the highest available land. Vegetation and foods occurring on these ridges are similar in kind to those described for the upper basin, but smaller in extent. The area of unflooded land available to deer changes as water levels in the swamp rise and fall. While deer will enter the shallow margins of swamps to seek food, the deeper swamps are not ordinarily used except for escape cover or during times of food stress.

Little is known of deer or deer conditions in the marsh area of the lower basin. Marsh deer are not often hunted because of the difficulties faced by the hunter in movement through and transport of killed animals from the marsh. Deer in the marsh again utilize available high land, including spoil banks and the very low natural levees of bayous. Most of the more desirable deer food plants in the marsh are confined to the high land areas.

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[99] Ibid.

[100] Needs and Goals Sub-Committee, 1973, op. cit.

Squirrels (*Sciurus niger* and *Sciurus carolinensis*)

St. Amant considers the Upper and Lower Mississippi River alluvial plain, including the Atchafalaya Basin and other large river flood plains in the state, to be the best squirrel range in Louisiana and possibly in the United States.[101] Two subspecies of gray squirrels (*Sciurus carolinensis*) and three subspecies of fox squirrels (*Sciurus niger*) occur in Louisiana. Those inhabiting the Atchafalaya Basin are *Sciurus carolinensis fuliginosus* and *Sciurus niger subauratus*. Gray squirrels are known to prefer dense, bottomland habitats, while fox squirrels prefer more open hardwood or mixed pine-hardwood forests.[102] *Sciurus niger subauratus* is, however, an exception in this regard and is found in bottomland hardwood areas and in cypress-tupelo swamps.[103] Although gray squirrels are somewhat more numerous statewide than fox squirrels, St. Amant found, on the basis of four years of bag checks, that fox squirrels slightly outnumbered gray squirrels in the Mississippi alluvial plain.[104] It is not known whether this condition obtains in the Atchafalaya Basin, with its more extensive swamps.

The best squirrel habitat in the basin, again, is in the upper basin above Interstate Highway 10.[105] This area contains a greater percentage of mast-bearing trees such as wateroak, overcup oak, pecan, and hickory, than the middle and lower parts. On a north-south gradient associated with drainage and sedimentation, the basin is vegetated by bottomland hardwoods in the northern end, becoming increasingly dominated by willow to the south, with the most unaltered cypress-tupelo swamp areas occurring at the lowest end. This overall picture is complicated somewhat by the bottomland hardwoods occurring on ridges in the lower and middle basin. Squirrel numbers and distributions can perhaps be related to vegetative types, with highest populations occurring in bottomland hardwood areas and lowest numbers occurring in a large area of the middle basin which is dominated by black willow. Although squirrels often eat the tender buds and leaves of willows in the spring, the availability of other high quality squirrel foods is probably not as high in willow-dominated areas, especially on a year-round basis, as in the other vegetative types.

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[101] St. Amant, 1959, *op. cit.*

[102] *Ibid.*

[103] Lowery, 1974a, *op. cit.*

[104] St. Amant, 1959, *op. cit.*

[105] Needs and Goals Sub-Committee, 1973, *op. cit.*

Rabbits (*Sylvilagus floridanus* and *Sylvilagus aquaticus*)

Two species of rabbits are found in the Atchafalaya Basin. According to Lowery, the cottontail rabbit (*Sylvilagus floridanus*) is most frequently found in more open habitats such as pastures, grassy fields near croplands, and the like, while the swamp rabbit (*Sylvilagus aquaticus*) prefers wooded areas, swamps, and marshes.[106] St. Amant, however, treated both species as farm game.[107] Undoubtedly, there is some overlap in habitats occupied by the two species, but, in general, swamp rabbits inhabit forest areas, and cottontails are found most often in or near cleared areas.

Rabbit populations are generally high in areas where habitat conditions are suitable, in spite of heavy hunting pressure and high mortality due to predation by hawks, owls, bobcats, and other predators. High numbers are maintained by the high breeding rate of rabbits and their general adaptability to a wide variety of habitat conditions and food plants. Besides their usefulness as game animals, rabbits play an important ecological role as a source of food for predacious birds and mammals in the basin.

Woodcock (*Philohela minor*)

The American woodcock, which is mostly a winter resident in Louisiana, is not a major game bird in the state,[108] and most woodcocks are killed incidentally by hunters seeking other game. The Atchafalaya Basin is, however, a major wintering area for woodcock in the United States, and woodcock hunting is more prevalent in the basin than in other areas of the state. These birds seek heavily wooded areas with dense undergrowth for cover during the daylight hours and fly into wet agricultural fields or other cleared areas at night to probe for earthworms or other ground-dwelling organisms.

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[106] Lowery, 1974, *op. cit.*

[107] St. Amant, 1959, *op. cit.*

[108] *Ibid.*

Mourning Dove (*Zenaida macroura*)

The mourning dove is a year-round resident in Louisiana. However, its numbers are greatly increased in the winter months with the arrival of migrants from the north. Mourning doves are popular game birds in the state. They are most abundant in and near cleared lands and agricultural areas, where they feed on the seeds of weeds, grasses, and cultivated plants, such as doveweed (*Croton* sp.), ragweed, corn, soybeans, rice, and sorghum.

Most of the doves in the basin occur in the cleared agricultural areas in the northern basin and in cleared areas on each side of the floodway. These are also the areas where they are most frequently hunted. St. Amant states that the Lower Mississippi-Atchafalaya alluvial plain "... no longer supports the large [dove] concentrations that it supported in earlier years"[109] and suggests that clean farming practices, such as winter plowing, increased grazing, and a decrease in rotation of legumes, grains, and fallow fields, have eliminated much of the natural and planted dove foods in the area. Since 1959, however, a tremendous increase in soybean acreage may have partially improved this condition.

Black Bears (*Euarctos americanus*)

A few native Louisiana black bears were known to occur in the Lower Atchafalaya Basin in the early 1960's.[110] In the mid-1960's, the Louisiana Wild Life and Fisheries Commission introduced 130 bears into the northern part of the basin in Pointe Coupee Parish. Although many of these bears wandered widely, an unknown number remained in the area and have reproduced. The hunting season on bears (a big game species) has been closed since the early 1960's except for this past 1974-75 hunting season, when bear hunting was allowed in an area near the site of introduction. At least one bear was killed during this season.

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[109] *Ibid*.

[110] Joe L. Herring, "Black Bear in Louisiana" (Louisiana Wild Life and Fisheries Commission Wildlife Education Bulletin No. 22, Louisiana Wild Life and Fisheries Commission, New Orleans, Louisiana, 1962).

Wild Turkey (*Meleagris gallopavo*)

Wild turkeys have been introduced into the basin in Pointe Coupee and Iberville Parishes. The turkey population in Pointe Coupee Parish has increased to the point where hunting is allowed. The highest ridges in the basin may have originally supported a few turkeys, but early authors, cited by St. Amant, concluded that turkeys were originally rare or absent in cypress-tupelo swamp areas.[111]

Bobwhite (*Colinus virginianus*)

Bobwhites are generally considered upland game birds, and in Louisiana most are found on farmlands, cut-over pine lands, and sparse longleaf pine woods.[112] In the Atchafalaya Basin, most bobwhites are found on farmlands in the northern basin and on either side of the floodway. Huntable numbers of bobwhites occur only in the farmlands where they are sought by a limited number of hunters with bird dogs.[113]

Foxes (*Vulpes fulva* and *Urocyon cinereoargenteus*)

Fox hunting is a minor sport in Louisiana, and most foxes are probably killed by hunters seeking other game. Both species are widely distributed in the state and are perhaps most abundant in upland areas in mixed pine-hardwoods with interspersed clearings.[114] Foxes also occur in the vicinity of farmlands in alluvial bottomland areas, and it is in these areas where they are perhaps most common in the Atchafalaya Basin. Foxes are also trapped for their pelts, but usually only a small number of pelts are taken. Food items eaten by foxes include small mammals, such as rats, mice, and rabbits, and some vegetable material.

Raccoons (*Procyon lotor*)

Raccoons are one of the major furbearers in the basin, and they are pursued to a limited extent as a game animal. Most coon hunting is done at night with dogs. In this form, it is limited mostly to higher land areas in the northern part of the basin. Raccoons are also killed in the lower basin incidental to other types of hunting. Some of the raccoon pelts taken in the basin are from animals which were shot rather than trapped.

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[111] St. Amant, 1959, *op. cit.*

[112] *Ibid.*

[113] Needs and Goals Sub-Committee, 1973, *op. cit.*

[114] Lowery, 1974a, *op. cit.*

Opossums (*Didelphis virginiana*)

The lowly opossum is probably a more important game animal than is usually realized, and it may be an important supplementary food item for many low-income families. The opossum is abundant in the basin and is rather easily taken. It is also trapped for its fur.

Bobcats (*Lynx rufus*)

Bobcats are present in all heavily wooded areas of the Atchafalaya Basin in "appreciable numbers."[115] They are hunted as a trophy animal, but the sport is of a relatively minor nature. Bobcats occupy a high position in the trophic structure of the terrestrial component of the basin ecosystem. They have few predators other than man, although occasionally a kitten may succumb to an owl or a hawk. Rabbits, mice, and rats make up a large portion of the bobcat's diet. Predation by bobcats on deer--mostly fawns--is only of minor occurrence, and most deer eaten by bobcats are believed to be carrion.

Snipe (*Capella gallinago*)

The common snipe is a winter resident mostly in the marshes of south Louisiana, including the marsh area of the Atchafalaya Basin. Snipe also occur around lake shores and grassy fields in more northerly areas. These birds are similar to woodcocks in their habits, except for their greater utilization of the marsh and their tendency to be somewhat more active in the daytime. Hunting for snipe takes place mostly in the marshes of the lower basin.

Rails (*Rallus elegans* and *Rallus longirostris*)

The king rail (*Rallus elegans*) and the clapper rail (*Rallus longirostris*), like snipe, are inhabitants of marshes, but are year-round residents. The king rail prefers fresh marsh situations and may be found also in wet fields and roadside ditches. The clapper rail, however, is almost never found outside of brackish or saltwater marshes. The Virginia rail (*Rallus limicola*) and the sora (*Porzana carolina*) are smaller game birds which are winter residents in the marsh. The coastal marsh area is the major habitat for these birds in the basin, and hunting for rails, which is undertaken by only a few select sportsmen, is confined to the marsh. Most rails are killed incidentally by duck hunters.

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[115] *Ibid.*

Bullfrogs

Bullfrogs (*Rana catesbeiana*) are sought both commercially and for sport in the Atchafalaya Basin. The pigfrog (*Rana grylio*), which is not as abundant nor as widespread as the bullfrog, probably makes up a minor portion of the catch. Reported catches during the 1963-1973 period indicate an average of about 32,000 pounds per year coming out of the basin.[116] According to Comeaux, most frogs are caught shortly after the season opens, although some frogging continues throughout the year, except during April and May, when the season is closed.[117]

General Comments Concerning Game Animals

Although presently all of the Atchafalaya Basin serves as a valuable habitat for game animals, the northern portion of the basin, forested by tree species which are somewhat more adapted to higher or better-drained lands, or sufficiently high or well-drained enough to allow cultivation, appears to be best-suited to most game species. The presence of many mast-bearing trees and the larger area of land which is not subject to flooding are factors which increase the value of the upper basin as a deer and squirrel habitat. Bears also rely heavily on mast for food.

Floods limit the development of a deer population by driving the animals to the highest available lands, where severe competition for available foods may lead to starvation. Deer stranded by floods are also subject to outbreaks of disease and are vulnerable to illegal hunting. It was only through the concerned efforts of personnel of the Louisiana Wild Life and Fisheries Commission, the United States Army Corps of Engineers, and private citizens during the 1973 flood when the Morganza Spillway was opened that widespread mortality among the deer herd was avoided.

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[116] D. Allen, National Marine Fisheries Service, New Orleans, personal communication.

[117] Malcolm L. Comeaux, "Atchafalaya Swamp Life, Settlement and Folk Occupations," in *Geoscience and Man*, ed. Bob F. Perkins (Volume II, Baton Rouge, Louisiana: School of Geoscience, Louisiana State University, 1972), p. i-xiv, 1-111.

Such species as cottontail rabbits, doves, and quail most often inhabit and develop highest populations in cleared or relatively open areas--so much so that they have been classified as "farm game" by St. Amant in a wildlife inventory of Louisiana.[118] Woodcock depend heavily on cleared areas for feeding, and foxes are usually most abundant in the vicinity of cleared land. Areas suitable for farming in the Atchafalaya Basin occur in the upper basin and in protected areas outside of the floodway.

Turkeys were probably originally distributed over most of the upland areas of the state and on the broad and high natural levees of major rivers. St. Amant does not consider the Lower Mississippi alluvial plain as an area which can be successfully managed for turkeys.[119] The stocking of turkeys into areas of Pointe Coupee and Iberville Parishes takes advantage of the somewhat higher land in these areas and its protection from flooding. Flooding during the nesting season may destroy turkey eggs or young or prevent nesting, as probably occurred to some extent during the 1973 flood.

Thus, it appears that many terrestrial game species in the Atchafalaya Basin are best suited to relatively drier habitats--dry enough to support abundant mast-bearing trees or, for farm game, to allow clearing for cultivation. Flood control measures in the basin which would cause drainage of backswamp areas, although having drastic effects on aquatic and aquatic-related resources, would also initiate a succession towards vegetation more characteristic of drier areas and have beneficial effects on terrestrial game species.

Other Wildlife

The other wildlife[120] of the Atchafalaya Basin includes a myriad of invertebrates, fishes, amphibians, reptiles, mammals, and birds. Time and space do not permit a detailed discussion of these forms, but their importance should not be overlooked. These species are the basic structural and functional elements of the swamp ecosystem, whereas game animals, game and commercial fishes, and waterfowl are only its more visible or usable components.

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[118] St. Amant, 1959, *op. cit.*

[119] *Ibid.*

[120] For convenience, the word "wildlife," which usually refers to vertebrate animals exclusive of fishes, is expanded in meaning here to include invertebrates and fishes.

Invertebrates

Invertebrates are perhaps the most important animal group in the basin. Including such diverse forms as protozoans, sponges, coelenterates, flatworms, rotifers, nematodes, bryozoans, oligochaetes, arthropods, and mollusks, invertebrates are a vast source of food for vertebrate animals as well as other invertebrates. The numbers and diversity of invertebrates, their diverse food and feeding habits, larval stages, and habitats contribute greatly to the stability of Atchafalaya Basin ecosystems.

Fishes

Besides game and commercial fishes, the waters of the area are habitats for numerous other fishes which have no sporting or commercial value. Of 77 species caught by Bryan *et al.*, 47 were non-game or non-commercial species.[121] Included in this category are such small fishes as minnows, topminnows, silversides, darters, and small sunfishes. Bryan *et al.* found mosquitofish (*Gambusia affinis*), silversides (*Menidia spp.*), bullhead minnows (*Pimephales vigilax*), and silverband shiners (*Notropis shumardi*) to be most abundant and most frequent in occurrence in seine collections taken in the basin.[122]

Most of the small fishes feed on small invertebrates, such as insect larvae, cladocerans, and amphipods, and are themselves food for larger fishes, wading birds, and other animals.

Amphibians

At least six species of salamanders and thirteen species of frogs and toads occur within the basin.[123] Among the salamanders, two species, the central newt (*Notophthalmus viridescens*) and the congo eel (*Amphiuma tridactylum*), are fairly common. The central newt, an aquatic species, can often be seen swimming along the edges of bayous where it forages for small crustaceans and insects. These newts are undoubtedly eaten by many predator fishes. The congo eel usually lives in holes or dens in the bottom mud of swamps, where it lays in wait of such prey as crawfishes, small finfishes, or frogs.

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[121] Bryan *et al.*, 1974, *op. cit.*

[122] *Ibid.*

[123] U.S. Department of the Interior, 1974, *op. cit.*

Frogs and toads and their tadpoles are utilized as foods by a number of basin inhabitants including predator fishes, congo eels, snakes, wading birds and kingfishers, minks, otters, and man. The bullfrog (*Rana catesbeiana*) and the pigfrog (*Rana grylio*) are commercial species. Frogs and toads of all kinds feed heavily on insects, and the more aquatic forms feed also on crawfishes and small fishes. Frogs feed on many insects which have aquatic larval stages, furnishing only one of many examples of energy links between the aquatic and terrestrial environments.

Reptiles

Reptiles definitely occurring in the Atchafalaya Basin include the American alligator, twelve species of turtles, four species of lizards, and twenty species of snakes.[124] Most of the reptiles occurring in the basin are aquatic forms.

The American alligator (*Alligator mississippiensis*), currently listed as an endangered species, occurs within the floodway portion of the Atchafalaya Basin in "extremely low" numbers.[125] They are probably more numerous in the fresh marsh areas in the lower basin below Morgan City. Alligators are generally responding to protection and increasing in numbers in the coastal marshes and swamps in southeastern Louisiana. Nichols attributes low numbers of alligators in the basin to illegal hunting activities,[126] but it is also possible that highly fluctuating water levels in the basin have inhibited reproductive success of alligators by flooding of nests.

Chabreck conducted food habit studies of young alligators (average total length = 1.06m in freshwater areas and 1.16m in saline areas) living in fresh and brackish water marshes on the Rockefeller Wildlife Refuge in southwestern Louisiana.[127] Reported food items include insects, crawfish, grass shrimp, spiders, birds, snakes, and fish in the freshwater areas, and insects, crawfish, blue crabs, fiddler crabs, and fish in the brackish water areas. Fur-trappers in the marsh complain of alligators preying upon muskrats and nutria. Adult alligators, in turn, have few predators (other than man);

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[124] *Ibid.*

[125] Nichols, 1973, *op. cit.*

[126] *Ibid.*

[127] Robert H. Chabreck, *The Foods and Feeding Habits of Alligators from Fresh and Saline Environments in Louisiana* (Proceedings, 25th Annual Conference of the Southeastern Association of Game and Fish Commissioners, 1971).

However, alligator eggs and newly hatched alligators are preyed upon by raccoons[128] and possibly other carnivores.

The sight of painted turtles basking in the sun on emergent logs is a familiar one in the Atchafalaya Basin. At least 13 species of turtles occur here,[129] and several species are gathered as food by local residents. All of the turtles in the basin, except for the Gulf Coast box turtle (*Terrapene carolina*), which will seek wet places during hot, dry weather, are aquatic. They are not highly selective in their feeding habits and eat both animal and plant matter. Snails and other mollusks, insects and insect larvae, and crawfish are taken by most turtles. Dead animals, mostly fish, are also eaten. Painted turtles and map turtles are more herbivorous than other species, while snapping turtles, stinkpots, mud turtles, and soft-shelled turtles are more carnivorous. Box turtles feed on mushrooms, insects, snails, myriapods, dead animals, blackberries, and other fruits.[130] These animals come ashore to lay their eggs in holes dug in the soil. Turtle eggs and young are subject to predation by roving mammals, and small turtles in the water are eaten by predator fishes, snakes, and birds.

Only four lizard species, the green anole (*Anolis carolinensis*) and three skinks, are known to definitely occur in the floodway portions of the basin.[131] Other species are likely to be found, particularly on the higher ridges surrounding the area. Lizards feed almost exclusively on insects and are, in turn, preyed upon by snakes, birds, and small mammals.

At least 20 species of snakes occur within the Atchafalaya Floodway.[132] Water snakes (genus *Natrix*), particularly, are abundant and quite conspicuous. Three species of poisonous snakes, the southern copperhead (*Agkistrodon contortrix*), the western cottonmouth (*Agkistrodonpiscivorous*), and the canebrake rattlesnake (*Crotalus horridus*), are definitely known to occur in the basin; two others, the Texas coral snake (*Micrurus fulvius*) and the western pigmy rattlesnake (*Sistrurus miliarius*), are found in near-basin localities and are suspected to occur inside the basin. The western cottonmouth is abundant in the basin, although it is often confused with the diamond-backed water snake (*Natrix rhombifera*), and its numbers are sometimes exaggerated. Snakes are carnivorous and, according to their habits, feed on a variety of organisms. Aquatic forms feed on fishes, crawfishes, congo eels, salamanders, and frogs, while more terrestrial forms feed on earthworms, insects, snails, toads, lizards, other snakes, small mammals, and birds. Predators on snakes include man, skunks, raccoons, bears, feral hogs, shrews, wading birds, owls, hawks, predacious fishes, alligators, turtles, and other snakes.[133]

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[128] Joanen, 1969, *op. cit.*

[129] U.S. Department of the Interior, 1974, *op. cit.*

[130] Clifford H. Pope, *Turtles of the United States and Canada* (Volume 28; New York: A. A. Knopf, 1939), 343 p.

[131] U.S. Department of the Interior, 1974, *op. cit.*

[132] *Ibid.*

Birds

The bird life of the Atchafalaya Basin is conspicuous and quite diverse. A survey of authoritative texts on the birds of Louisiana indicates that approximately 140-150 species of birds (including waterfowl and other game birds), representing 17 orders and at least 42 families, may be expected to occur in the Atchafalaya Basin either as permanent or seasonal residents or visitors.[134,135] Such a diversity of species is not surprising in view of the location of the basin at the southern terminus of a major migration route and the numbers of different habitats for birds. These include farmlands and towns, bottomland hardwood forests and wooded swamps, open water lakes, bayous, and rivers, fresh, brackish, and salt marshes, and beaches, all of which may be found in the natural Atchafalaya Basin.

Many of the birds in the basin are characteristic inhabitants of wetlands. They are dependent, to a great extent, on aquatic organisms, such as aquatic plants, fishes, crawfishes, grass shrimp, snails, and insects (either adult aquatic insects or insects with aquatic larvae) as a food source and are thus directly linked through food chains to the aquatic environment. Any change in the aquatic environment which would reduce its area or decrease its productivity would cause a severe impact on many more-or-less terrestrial animals, such as birds, which are dependent upon aquatic productivity.

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[133] A. H. Wright and A. A. Wright, *Handbook of Snakes of the United States and Canada* (Ithaca, New York: Comstock Publishing Associates, 1957).

[134] George H. Lowery, *Louisiana Birds* (3d ed.; Volume 30, published for the Louisiana Wild Life and Fisheries Commission by Louisiana State University Press, Baton Rouge, Louisiana, 1974b), 651 p.

[135] Harry C. Oberholser, *The Bird Life of Louisiana* (Volume 12, published in cooperation with the Biological Survey, United States Department of Agriculture, by the Department of Conservation, New Orleans, Louisiana, 1938), 834 p.

Mammals

The known or presumed range of 41 species of mammals includes all or part of the Atchafalaya Basin.[136] The list includes familiar species, such as the opossum, the armadillo, rabbits, squirrels, raccoons, and deer, and also such little-known or surprising forms as bats, mice, rats, and black bears. Important furbearing mammals in the basin include the nutria, muskrat, raccoon, mink, and others (see section of this report on furbearers). Game species of mammals are discussed elsewhere in this report.

Although many of the mammal species in the basin are aquatic or are otherwise adapted to withstand flooded conditions, certain ground-dwelling species, such as shrews, rats, and mice, appear to be limited in their distribution to the highest land areas. Even among more or less aquatic species, such as the muskrat, floods may drown houses and young. Slowly rising waters, which allow ample time to seek refuge, do less damage than sudden massive floods, such as occurred when the Morganza Floodway was opened in 1973. Small mammal populations in the floodway have probably not yet recovered from the effects of this flood.

Species such as the opossum, shrews, the cottontail rabbit, harvest mice, and the cotton rat most often inhabit grassy fields or forest edges near agricultural or other cleared areas. Pests, such as the roof rat, Norway rat, and the house mouse do not only occur in houses, barns, and other outbuildings, but also in grassy fields and drainage ditches. They are consumed by such predators as hawks, owls, and bobcats, and thus have integrated into natural communities.

Coyotes and foxes usually inhabit upland areas and probably occur in the northern part of the basin in low numbers. The red fox is probably an introduced species. The coyote has spread into Louisiana from Texas since about 1950 and is now widespread in the northern part of the state.[137] Coyotes occur in limited numbers in the area of the Atchafalaya Basin.

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[136] Lowery, 1974a, op. cit.

[137] Ibid.

Bears have been introduced into the upper basin. A few native bears known to occur in the lower part and in the marshes south of Morgan City in the early sixties may still occur there.

The American beaver has in the past several years spread from more northerly parishes and extended its range into most of the Atchafalaya Basin.[138] The dam-building habits of beavers will likely pose interesting problems in the implementation of a water management program in the area.

Bats are important, although often overlooked, mammal species. They often live in the attics of old or abandoned houses or barns, but they (especially members of the genus *Lasiurus*) also may spend the daytime hours in hollow trees or clinging to tree branches or clumps of Spanish moss. Bats feed almost entirely on flying insects.

Mammals, like birds, have various food habits which range from herbivorous forms, such as harvest mice, rabbits, and deer, to insectivorous forms (bats) and omnivores, such as opossums, armadillos, and bears, to top carnivores, such as weasels, otters, and bobcats. Mammals, and indeed all life forms in the basin, are intricately linked in a many-intertwined web of food relationships.

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[138] Greg Linscombe, personal communication (February, 1975).

VI
THE LOWER ATCHAFALAYA BASIN

While some consideration has been given to the consequences of the use of the Atchafalaya Basin as a floodway, most attention has been concerned primarily with the swamp basin lying above the alluvial ridges of Bayous Teche and Black. Below this ridge, a whole set of different environmental conditions and processes must be reckoned with. The future development of the Atchafalaya River delta will have important impact over a zone extending from western Terrebonne Parish into Vermilion Parish, and numerous choices concerning a desirable pattern of delta growth and dispersal of water and sediment throughout this large area will need to be evaluated.

Terrebonne Marshes

In the western coastal segment of Terrebonne Parish, the marshes show several major problems that are closely related to the Atchafalaya River. In recent years, large areas of freshwater marshes formerly dominated by species such as the grass Panicum hemitomon and other herbaceous hydrophytes, such as Sagittaria falcata, have undergone degeneration and subsequent replacement by shallow water bodies (Figure 6-1). This process cannot be attributed with present knowledge to any single cause, but several contributing factors can be identified.

1) High stages on the lower Atchafalaya River during the spring tend to cause flooding over these marshes to levels that exceed the levels to which the marshes were adjusted when the Atchafalaya was a smaller river with lower stage variation.

2) Accumulation of sediment from the Atchafalaya River along the western edge of the Terrebonne marshes has partially impounded drainage from the inner marsh areas.

3) Numerous rig location canals and oil and gas pipeline canals have been excavated in the past three to four decades, leading to greater access of floodwater into the area and deeper flooding. Spoil banks from such canals have created severe impoundment over large areas. This same network leads to greater drainage during the low river stage in the dry season months, which exposes the highly organic marsh soils to deterioration through biological oxidation, shrinkage, and combustion from marsh fires, which are common. Thus, both excessive flooding and overdrainage can be a problem in the same area at different times of the year.

4) Water hyacinth has risen to dominance over most of the affected area, no doubt due to its indifference to flooded conditions. The hyacinths form a dense mat which smothers pre-existing vegetation when river stages fall.

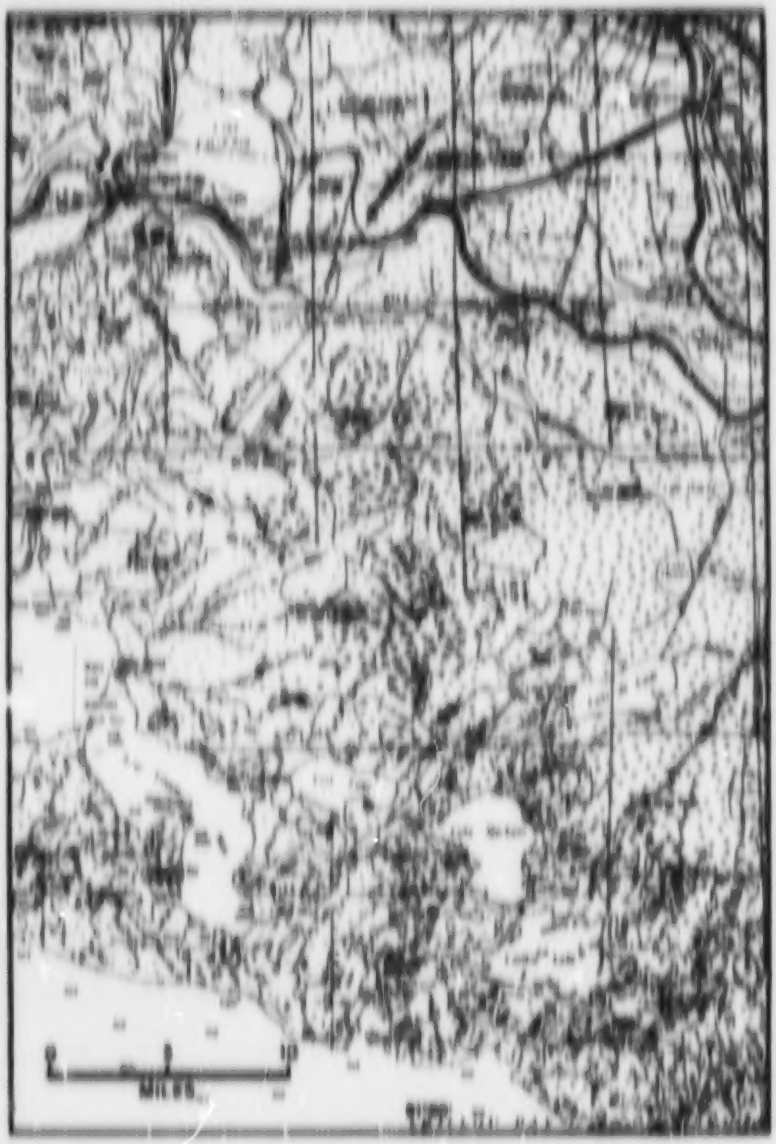

Figure 5-1. Extent of marsh replacement by shallow water bodies (shaded areas) as determined by 1974 aerial photos.

5) Natural subsidence, which is known to be occurring at about 1 m/century at nearby Eugene Island, must also be a factor in the marsh breakup. Unnatural subsidence due to the extraction of oil and gas from the several fields of the area is also likely to have contributed to an unknown extent to the problem.

6) After destruction of the natural vegetative cover of the marsh by any of several means suggested above, the organic soils may be quickly broken up and removed by wave erosion, especially at times when they are covered by water during storms.

The consequence of a continued rapid breakup of the marsh can be anticipated at the present time only to a certain degree. A lake should develop as the growing, shallow aquatic areas coalesce to greater size. To some extent, sedimentation will counteract this tendency, but it is not known at present if sedimentation will be of sufficient importance to restore the marshes. A growing depression in this area could lead to diversion of greater Atchafalaya River flow into the area, eventually creating a deltaic distributary lobe which would reverse the tendency for land loss. With the creation of the Chene-Boeuf-Black navigation channel, this process would be accelerated since greater amounts of Atchafalaya River water will enter via the enlarged channel. If the Chene-Boeuf-Black navigation channel is not constructed, then it might be possible to correct the problem of these deteriorating marshlands by controlled introduction of water and sediment through a smaller channel.

Another important problem in western Terrebonne Parish is that of drainage of water from the Lake Verret - Lake Palourde catchment basin. During times of high stage in the Lower Atchafalaya River, this water does not have an efficient outlet, but must escape by overland flow across the marshes or via a circuitous route along the Gulf Intracoastal Waterway (GIWW) and intersecting bayous and channels. Such flow is contributory to the problems of deteriorating marshes. More information on the routing of these waters will be required in order to suggest a strategy for alleviation of this situation.

The decline of oyster production in western Terrebonne Parish is also related to Atchafalaya River discharge, especially in years of large floods, such as 1973 and 1974. Formerly cultivated oyster beds in the area of Point au Fer and Four League Bay are no longer useable because of both excessive mortalities from low salinities and high turbidities and because they are condemned due to excessive coliform counts from wastes carried by the river waters. In 1973-74, high mortalities due to low salinities occurred as far eastward as Caillou Lake. The value of the natural and managed oyster areas destroyed by freshening is certainly great enough to justify efforts at remedying this situation. Caillou Lake has been estimated to yield 454.6 kilograms (kg) or 1,000 pounds (lbs)/acre of oyster meats when good conditions prevail.

A third problem in the western Terrebonne Parish area relates to the GIWW and potentially to the Chene-Boeuf-Black Waterway if it is constructed. The Chene-Boeuf-Black channels, even in their present state, carry water in times of high Atchafalaya River stage to the GIWW, by which it is carried eastward and distributed through various intersecting channels. The sediment and water distributed in this way may lead to future problems of channel maintenance.

Lastly, it should be said that the entire expanse of western Terrebonne Parish represents a large, high quality fish and wildlife habitat long used and valued by local inhabitants and persons from other areas. Although it has already been subjected to much destructive use, it remains one of the largest and least disrupted marsh habitat areas in Louisiana. It will undoubtedly suffer great and rapid impact from the growth of the future Atchafalaya Delta and, therefore, deserves comprehensive consideration in regard to its problems and alternatives for management.

Atchafalaya Delta

Deltaic sedimentation has become an increasingly dominant process in Atchafalaya Bay. Deposition of prodelta silty clays and clays has been ongoing since the nineteenth century, increasing with Atchafalaya River discharge and with gradual in-filling of the lakes north of the Teche Ridge. Coarse-grained sedimentation was initiated in the 1950's, and at present, bed-load sands are deposited at the mouths of Wax Lake Outlet and the Lower Atchafalaya River, having resulted in a distinct river-mouth bar at each channel.[139] Bottom topography of Atchafalaya Bay has become subject to rapid changes with numerous islands emergent during low tidal phases. Within much of the bay near the Lower Atchafalaya River mouth, water depths have been reduced to 0.3 m (1 ft). Cratsley shows that depths are less than 1.8 m (6 ft) throughout Atchafalaya Bay.[140] With deposition rates of as much as 0.1 m (0.3 ft) annually, the open-water expanse will soon be replaced by an emergent delta surface extending to the outer oyster reefs between Point au Fer and Marsh Island. Predictions are for the presence of about 777 km^2 (300 mi^2) of new land by the year 2020.[141]

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[139] D.W. Cratsley, *Recent Deltaic Sedimentation, Atchafalaya Bay, Louisiana* (M.S. Thesis, Louisiana State University, 1975), 142 p.

[140] *Ibid.*

[141] R.J. Shlemon, "Development of the Atchafalaya Delta, Louisiana" (Report No. 13, *Hydrologic and Geologic Studies of Coastal Louisiana*, Center for Wetland Resources, Louisiana State University, 1972), 51 p.

Associated with delta progradation, adjacent areas are and will be further affected. Initially, decreased depth and associated increased turbidity due to wave motion will allow greater sediment transport into adjacent areas due to wave-, tide-, and wind-generated currents. In particular, the generally westward water movement must be expected to contribute to a further reduction in depth of the adjacent Cote Blanche Bay system. Subsequent delta development, especially that of distinct distributary channels and associated natural levees, will likely reverse present effects on Terrebonne marshes and the Cote Blanche Bays for some time. With development of natural levees and increasing dominance of overbank flow processes, deposition of coarse fractions will become more localized along levee ridges while inter-levee areas become more protected, entrapping the finer, suspended materials. Also, confinement of most sediment transport to the distributary channels will ensure further seaward movement prior to dispersal. Thus, adjacent areas may eventually become bypassed by deltaic sedimentation for some time. However, such change must also be viewed as temporary since development of additional delta lobes through development of new distributaries may occur in a westward and/or eastward direction, as shown by historic developments of the Mississippi River delta.[142]

Requirements with regard to management of the emerging Atchafalaya Delta relate to the following subjects: flood control, navigation, and environmental quality. With regard to navigation, the requirement was previously stated as the need to separate the navigation route from the area of active delta building.

Concerning flood control, it should be pointed out that the developing delta becomes, in essence, an extension of the Atchafalaya Floodway through which water must be routed to the Gulf. This will require management of distributary channel development to ensure maximum hydraulic efficiency of the delta.

Environmental quality considerations concern primarily the adjacent areas of Cote Blanche Bay and the Terrebonne marshes. In neither case is there sufficient information on present conditions and trends available to warrant specific recommendations. Options for management of the Terrebonne marshes range from increased freshwater and sediment input to a return to a more saline environment with possibly high productivity. Further consideration should also be given to the possibility of managed changes in location of delta development.

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[142] S. M. Gagliano and J. L. van Beek, "Geologic and Geomorphic Aspects of Deltaic Processes: Mississippi Delta System" (Report No. 1, *Hydrologic and Geologic Studies of Coastal Louisiana*, Center for Wetland Resources, Louisiana State University, 1970), p. 140.

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A possible long-term delta management strategy is suggested by the natural delta cycle as registered by Louisiana's recent geologic history.[143] Prior to artificial fixation of the Mississippi River course in its present location, building and deterioration of delta lobes were concomittant processes associated with which were cycles of biological productivity related to the state of a particular delta lobe. Were natural processes to run their course, the western Terrebonne marshes, as part of the Lafourche delta lobe, must be expected to gradually open up into an estuarine system in which a length increase in land-water interface would increase productivity. This would be followed by an open-bay phase with decreasing productivity. At that time, possibly some one to two hundred years from present, the locus of delta growth may be forced through management toward the Terrebonne area to initiate a new cycle of deltaic evolution. Simultaneously, this would initiate the change toward a more saline and biologically productive system in the then fully developed Atchafalaya Delta. Management could thus be for alternate growth and deterioration in the two adjacent areas of Atchafalaya Bay and western Terrebonne.

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[143] S. M. Gagliano et al., "Environmental Atlas and Multiuse Management Plan for South-Central Louisiana" (Report No. 18, Volume 1, Hydrologic and Geologic Studies of Coastal Louisiana, Center for Wetland Resources, Louisiana State University, 1973), 132 p.

VII
BASIN HYDROGRAPHY AND HYDROLOGY

The key variables with regard to management options in the Atchafalaya Basin are surface elevation and water level. Taking into consideration their areal and temporal variation, these two variables are also the principal controls over fish and wildlife habitat and determine land use suitability for agricultural, urban, and industrial development. Water level, however, is only one aspect of basin hydrography. Additional consideration needs to be given to the source of water, its availability, and the manner in which its movement through the system is controlled.

Verret and Fausse Point Basins

Annual flooding and drainage are two factors that are highly relevant as land use constraints in the Atchafalaya Basin. Prepared by the United States Department of Agriculture (U.S.D.A.) Soil Conservation Service, Figure 7-1 shows the area flooded with a frequency of 40%, or twice every five years, during the months of June through November, excluding flood conditions generated by hurricanes or use of the Atchafalaya Basin Floodway. Inspection of gaging data shows that this distribution of the partial year is slightly conservative for areas outside the floodway. For instance, the U.S.C.E. gage at Pierre Part in the Verret Basin for the period of 1961 through 1972 reveals that highest stages occur in April, with an average of 0.58 m (1.89 ft) mean sea level (MSL). Highest stages during the period of June through November occur in September, when the average stage is 0.50 m (1.63 ft) MSL.

South of the Teche and Black Ridges, the flooded lands include the entire coastal area, with the exception of the natural levee ridges along Bayou Cypremont and Bayou du Large and the artificially protected ridge along Bayou Sale. Flooding of the coastal area has multiple causes which may occur individually or in combination. Among these are high Atchafalaya River discharges, local rainfall, and wind-generated tides. The effect of high Atchafalaya River discharges relates to the diversion of flow into channels ancillary to the Lower Atchafalaya River and Wax Lake Outlet as referred to earlier.

In the Fausse Point and Verret Basins, flooded conditions are seen to regularly prevail as far north as Interstate 10. The flood-prone area in the Fausse Point Basin comprises the wetlands around Lake Fausse Point, where the natural levee ridge of Bayou Teche is most distant from the floodway-guide levee, so that a depression is formed. Being the lowest part of the Fausse Point Basin, this depression collects much of the local runoff from that basin. Surface runoff from the extensively farmed Teche levee ridge is directed eastward toward

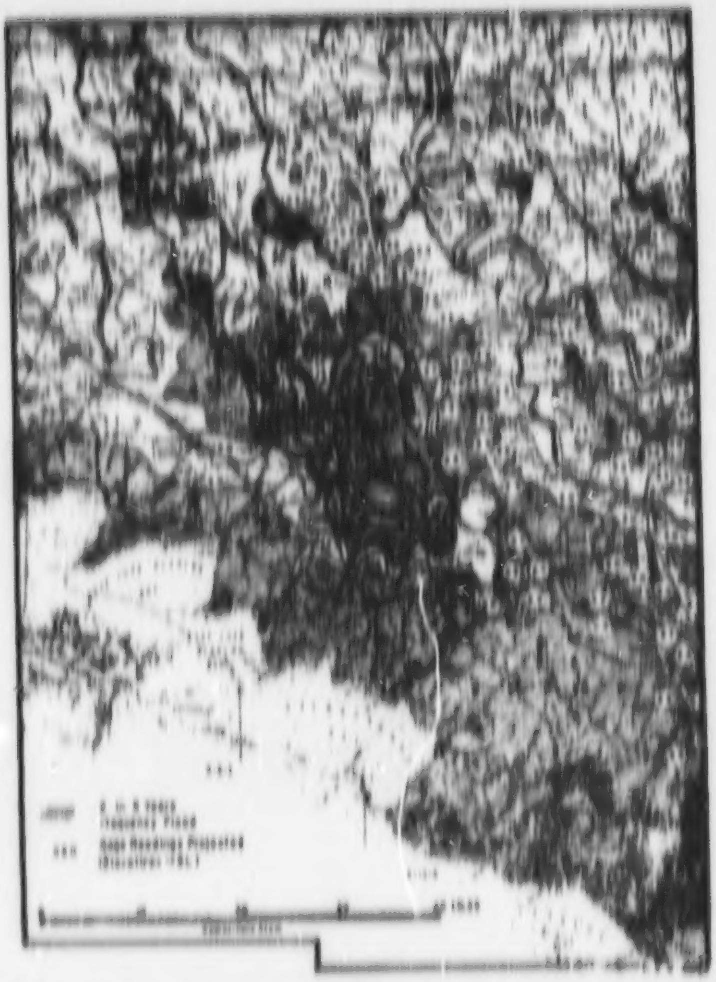
2 in 5 Years
Frequency Flood
Gage Readings Projected

Figure 7-1. Areas where flood frequency equals or exceeds 40 percent during the period of June through November.[144,145]

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[144] U.S. Department of Agriculture, Flood Frequency Contour Map, Areas 3 and 4 (Soil Conservation Service, Alexandria, Louisiana, 1973) 2 maps.

[145] U.S. Army Corps of Engineers, 1974, *op. cit.*

the floodway-guide levee, where it is collected by the levee borrow-pit and routed into Lake Fausse Point. Drainage from the Fausse Point Basin is provided through the Charenton Drainage and Navigation Canal into West Cote Blanche Bay. This condition makes water levels in the Fausse Point Basin dependent on local runoff as well as water level in the coastal area. Prolonged high tidal levels as a result of wind set-up may greatly impede drainage. The same obstruction to drainage may be caused by high river stages in Wax Lake Outlet and associated diversion of flood water through the Intracoastal Waterway into the Charenton Canal.

As illustrated by Figure 7-1, the flood-prone area in the Verret Basin to the east of the floodway is much more extensive; yet causes of flooding are similar to those in the Fausse Point Basin. The natural levee ridges of the Mississippi River and Bayou Lafourche are distant from the floodway-guide levee, leaving an extensive, north-south oriented depression. Inherent to the natural levee slope, all flow is directed toward this depression, which has only one major outlet, Bayou Boeuf.

As in the case with the Fausse Point Basin, the Verret Basin represents a distinct hydrographic unit, with water input entirely dependent on local rainfall. Using the methods developed and described in the previous study,[146] it is calculated that total annual runoff generated within the Verret Basin is in the order of 1.335×10^6 m^3 (44.5×10^6 ft^3). Runoff values are highest during February, when they attain an average value of $.273 \times 10^6$ m^3 (9.1×10^6 ft^3) and lowest during August, with an average value of 6000 m^3 (0.2×10^6 ft^3). The overall slope of the basin directs water to the southwest toward the eastern floodway-guide levee and into Lake Palourde.

With the natural levee ridges of Bayou Black blocking southward disposal of runoff into the coastal wetlands, a major constraint is placed on removal of water from the area. Based on inspection of the basin's drainage network, it is estimated that 80% of the total runoff leaves the basin through Bayou Boeuf, which crosses the Bayou Black ridge and connects Lake Palourde with Bayou Chene. The remaining runoff escapes through a number of drainage canals connecting the southeastern part of the Verret Basin with Bayou Black.

As a result of Bayou Chene, and consequently Bayous Boeuf and Black, being linked with the Lower Atchafalaya River, high Atchafalaya River discharges are associated with diversion of water into Bayou Chene and severely impede drainage from the Verret Basin. Such diversion has been found to occur 60% of the time.[147] High tidal levels in the coastal area have a similar effect. Under a combination of the above circumstances, flow in Bayou Boeuf may even be reversed, with additional water entering Lake Palourde from the south and further raising backwater flooding stages.

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[146] Coastal Environments, Inc., 1974a, *op. cit.*

[147] U. S. Army Corps of Engineers, 1974, *op. cit.*

For both the Fausse Point and Verret Basins, it becomes apparent that flood frequency and drainage constraints form a major limiting factor with regard to land-use options. Well-drained lands are coincident only with the major natural levee ridges of Bayou Teche, the Mississippi River, and Bayou Lafourche, along the margin of the basins, and along some additional older levee ridges within the upper Verret Basin north of Interstate 10. Marginally drained areas are found in the flood plains in the upper Verret Basin and along the smaller natural levees of the old Mississippi River or Lafourche distributaries or crevasse channels, such as Bayou Pierre Part, Little Bayou Black, and Bayou Black. Still, in many of the above areas, drainage remains problematic, particularly along the levee margins, where surface gradients are extremely low and surface-water removal is slow. For this reason, watershed protection and flood-prevention work have been planned in both basins by the U.S.D.A., Soil Conservation Service. In the Verret Basin, this work calls for a two-year level of protection for crops and pasture through realignment and modification of 230 miles of stream channels. These channels will provide a more rapid and direct drainage of surface water from the developed levee ridges into one or more major channels traversing adjacent wetlands and discharging into Lake Verret and Lake Palourde. Similarly, 356 miles of stream-channel realignment and modification are planned in the Fausse Point Basin.

Atchafalaya Basin Floodway

In the Atchafalaya Basin Floodway, flooding is in the first place related to Atchafalaya discharge, which attains highest values during the spring months. During normal high stages, nearly the entire area south of U.S. 90 is flooded. Overflow conditions occur in much of the area even during the dry and low months as shown in Figure 7-1. Two flooding processes are recognized in the floodway, the areas of which are roughly divided by Interstate 10. This may be further illustrated by Figure 7-2, which shows the movement of water during average high Atchafalaya stages.

North of Interstate 10, flooding can generally be described as backwater flooding. Atchafalaya River water diverted through Bayou La Rose to the west and through the East Freshwater Diversion Channel to the east, is forced northward toward the West Atchafalaya Floodway and Morganza Floodway, respectively. To this is added local runoff from the sizable watersheds represented by these floodways and by the Point Coupee area to the north of the Morganza Floodway.

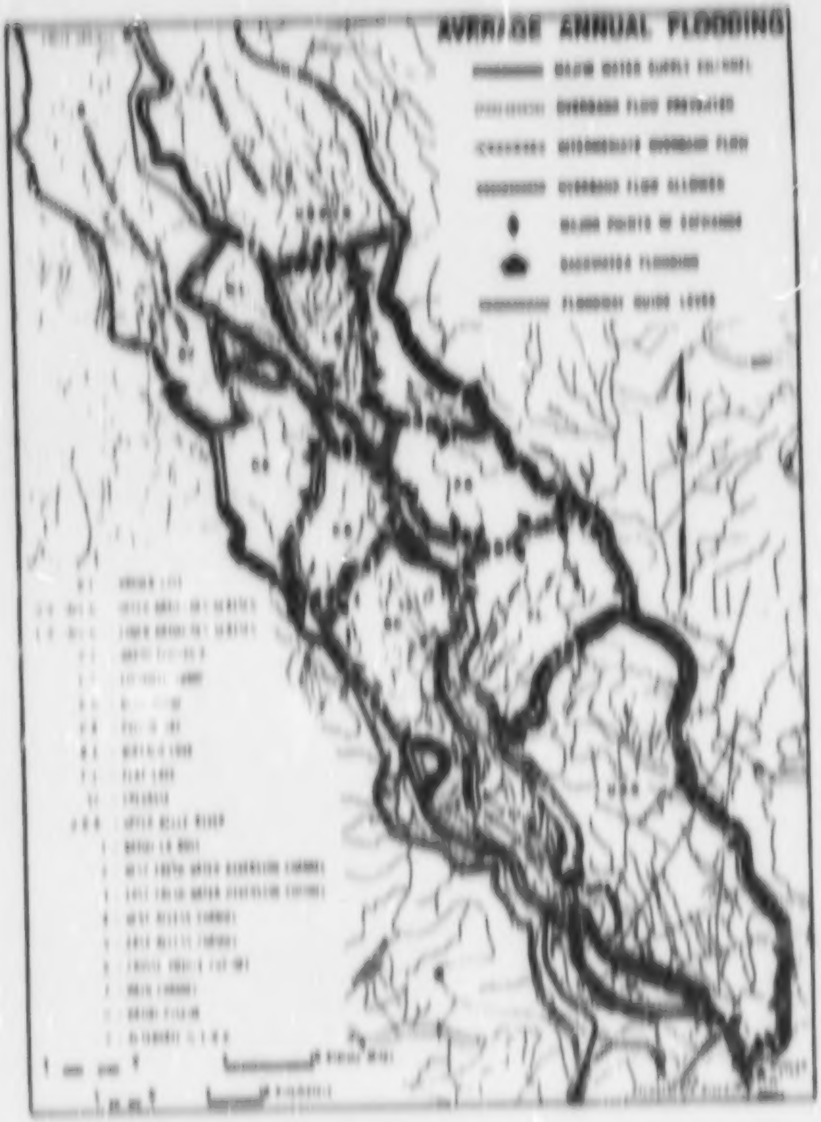
AVERAGE ANNUAL FLOODING

Figure 7-2. Diversion of Atchafalaya River flow into individual sub-basins through channel flow (arrows) and overbank flow.

Reproduced from best available copy.

To the south of Interstate 10, a totally different regime is present. As discussed in a previous report,[148] the topography of the Lower Atchafalaya Floodway is comprised of a series of sub-basins arrayed on either side of the Main Channel. The basins are separated from each other by distributary channels and associated natural levee or levee-spoil ridges. Spoil banks also separate each basin from the Main Channel. Under more natural conditions, these basins were flooded through annual overflow from the Atchafalaya River. During high stages, flood water covered the entire width of the floodway, with the exception of high natural levees and spoil banks. However, due to man's activities, this exception has become highly significant. Banks along the Main Channel and major distributaries have been raised by spoil to the extent that flooding for average high stages has predominantly become dependent on openings in the levee ridges that surround individual sub-basins.

Based on the mean annual maximum stages for the period of 1961 through 1970, topographic data obtained from the U.S.C.E. survey ranges, aerial-photo interpretation, and field inspections, the nature of flooding was determined for each of the sub-basins or management units. Comparison of the mean high water level at each intersection of a survey range and Main Channel (or major distributary) with bank-elevation allowed determination of the extent to which flooding occurs as a result of true overbank flow. True overbank flow occurs when water from a channel enters a sub-basin by overflowing the channel banks as opposed to being diverted from a channel into a sub-basin through a stream connecting the two.

Inspection of Figure 7-7 reveals that the majority of the sub-basins or management units are, on the average, not flooded through overbank flow but through channel flow. The map shows, respectively, banks not allowing overflow, banks allowing overflow, and major points of channel flow input. Overbank flow from the Main Channel is prevented in nearly all cases except along the lower margins of the Crevasse and Upper Belle River Units. Overbank flow is also prevented along most of the length of the distributaries, East and West Access Channels, East and West Freshwater Diversion Channels, and Fausse Point Cut-off.

Natural conditions have been maintained most closely in the southeastern part of the floodway bounding the alternate Intracoastal Waterway. Water diverted into the waterway by the eastern distributaries annually overflows its banks into Flat Lake and Upper Belle River. Bayou Pigeon, receiving flow from the Intracoastal Waterway, also allows annual overflow. Additional overflow is possible through backwater diverted from the Main Channel into Lake Chicot, which also serves the Crevasse unit.

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[148] Coastal Environments, Inc., 1974b, *op. cit.*

The remaining management units are seen to be flooded predominantly through channel flow provided for by secondary channels or mineral industry canals. In some cases, water is allowed to enter from all sides, such as in Pigeon Bay. In other cases, such as in the management units to the west of the Main Channel, flooding is largely a backwater process, with water entering mainly from the side or lower end.

Conditions where flooding is mainly dependent on diversion of water from a major sediment-carrying channel through channel flow are highly undesirable, as illustrated by Buffalo Cove Management Unit.[149] Water enters the sub-basin at a high velocity and for some distance carries a substantial volume of sediment, which is eventually deposited in the swamp interior as water disperses. Inherently, intensity of this process is inversely proportional to the number of channels serving a particular sub-basin.

The above conditions stand in strong contrast to overbank flooding, where flow velocities decrease immediately adjacent to the water-supplying channel, and sediment is deposited on the channel banks. Thus, channel flow tends to equalize elevations by filling in the low areas, whereas overbank flow tends to maintain the basin shape by elevating the rim. Areas where overbank flooding is dominant, such as Upper Belle River and Flat Lake, have experienced minimal increases in elevation of the swamp floor. Sedimentation has occurred predominantly along the southern margins, where the Main Channel is directly connected with a number of lakes.

Where backwater flooding is the only process by which water enters a swamp basin, it leads to diminished circulation or water replacement away from the point of water input. As illustrated by the northern half of the Buffalo Cove Management Unit, insufficient circulation results in water quality problems in areas where water is present throughout the year. The above condition contrasts with those areas such as Bayou Fordoche and upper Bayou des Glaises, which experience backwater flooding, but have an open upper boundary where local runoff provides an annual flushing effect.

The previous evaluation of flooding characteristics is partially based on computation of water levels in the major channels throughout the Lower Atchafalaya Floodway. The first step in this computation is a compilation of daily stages for the period of 1961 through 1970 for all U.S.C.E. gaging stations. Location of these stations is shown in Figure 7-3. Monthly averages for the ten-year period are then calculated for each gaging station utilizing relationships between proximate gages to fill in data gaps where records are incomplete. A computer program developed to determine water levels at intermediate points on the basis of linear interpolation is then used. Intermediate points include all U.S.C.E. range-line intersections and all major points of

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[149] Coastal Environments, Inc., 1974b, _op. cit._

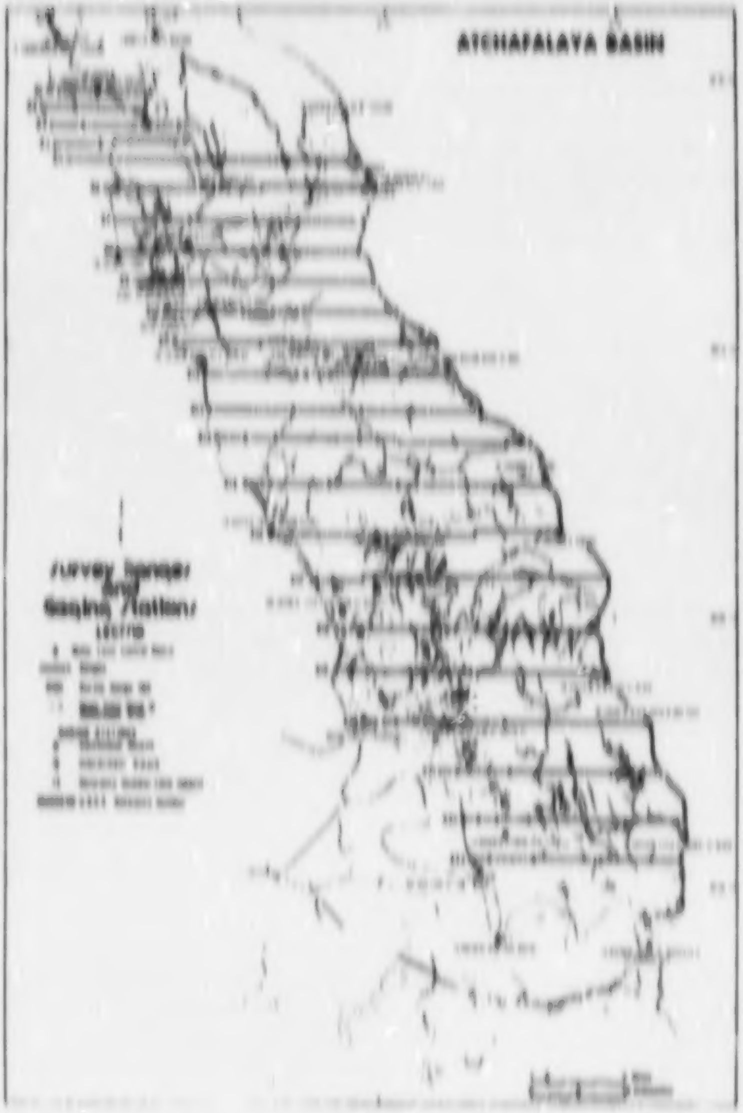
ATCHAFALAYA BASIN
Survey Ranges and Gaging Stations
LEGEND

Figure 7-3. Locations of U.S.C.E. topographic survey ranges and stage gaging stations, and of data control points used in calculation of sub-basin water levels.

flow diversion. Figure 7-2 shows all points for which average monthly mean water level has been determined. The following paragraphs utilize these data to further evaluate present and proposed (as related to the Center Channel) hydrographic conditions in the swamp sub-basins of the floodway.

Sub-Basin Hydrographs and Hydroperiods

Annual variations of water level are considered to be one of the major contributing factors to productivity of the floodway swamps. Changes regarding maximum and minimum variation are one of the concerns related to the possible impact of proposed Center Channel dredging. Monthly mean water levels as obtained through the previously described program are therefore utilized in 1) estimating present extent and duration of flooding in the various sub-basins or management units, 2) evaluation of the changes to be brought about by dredging of the Center Channel, and 3) development of a possible hydrograph for water-management purposes.

The first step is to relate channel stages obtained at the locations shown in Figure 7-3 to water levels representative of individual sub-basins. In the absence of stage observations within the sub-basins and within the constraints of available time, the best approximation is considered to be a weighted combination of channel stages and channel locations, with weighting dependent on the location, nature, and relative magnitude of flow from a channel into a sub-basin. Necessarily, this method ignores water-surface slope within a sub-basin.

The second step is a compilation of data for proposed Center Channel conditions. To accomplish this dual rating, curves in terms of Simmesport discharge were developed for all possible spring stages utilizing results from the U.S.C.E. fixed-bed model study.[150] These curves, illustrated in Figure 7-4 for Upper Grand Lake, were used to adjust calculated mean stages at the gaging stations of Figure 7-3 to future conditions of the Main Channel. The adjusted data were then processed in the same manner as the ten-year period data to obtain intermediate channel stages and sub-basin water levels.

As an example, the two obtained hydrographs, present and future, are shown in Figure 7-5 for the Buffalo Cove Management Unit. The hydrographs indicate that Center Channel construction would lower water levels about two feet in late summer and early fall under normal conditions, and about five feet during the spring season. Since stage reductions along the Main Channel increase in an upstream direction, most management units further upstream would experience a somewhat greater reduction in water levels. Tables 7-1 and 7-2 summarize these facts for each of the individual management units within the floodway.

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[150] U. S. Army Corps of Engineers, 1974, *op. cit.*

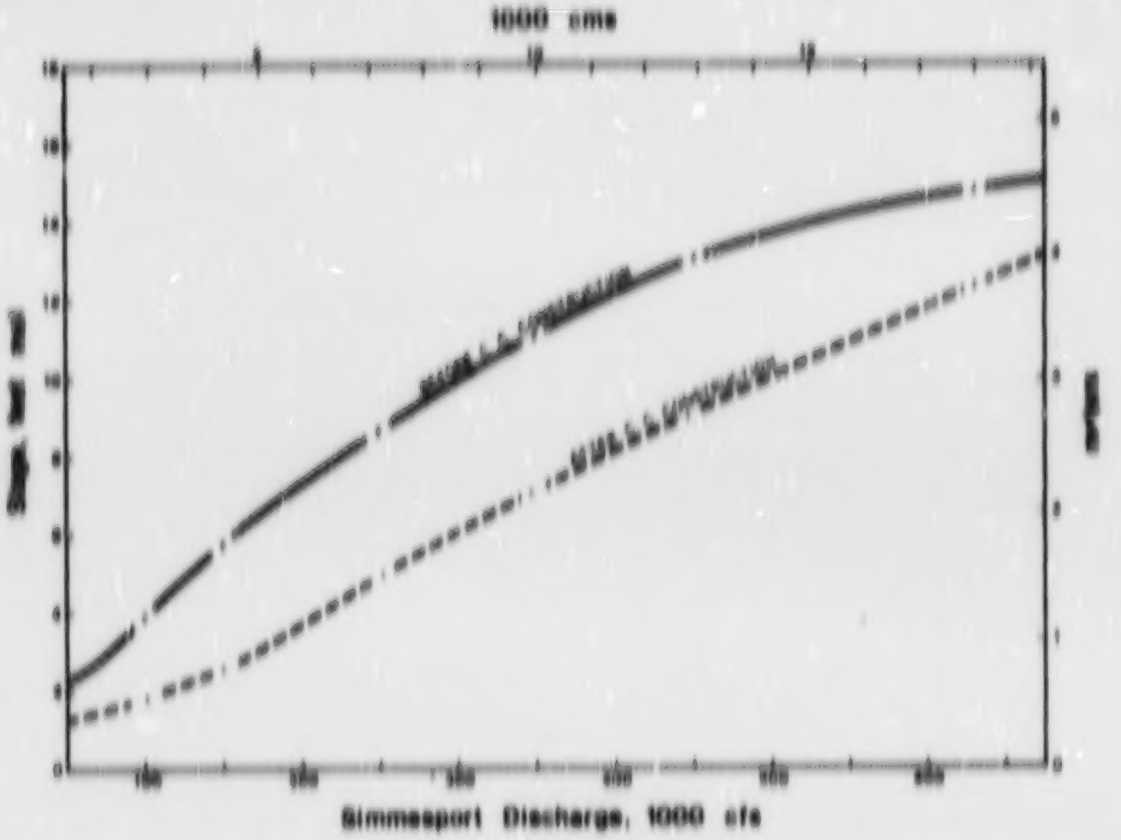

Figure 7-4. Stage-discharge relationships at Upper Grand Lake for conditions at present and after proposed Center Channel dredging.

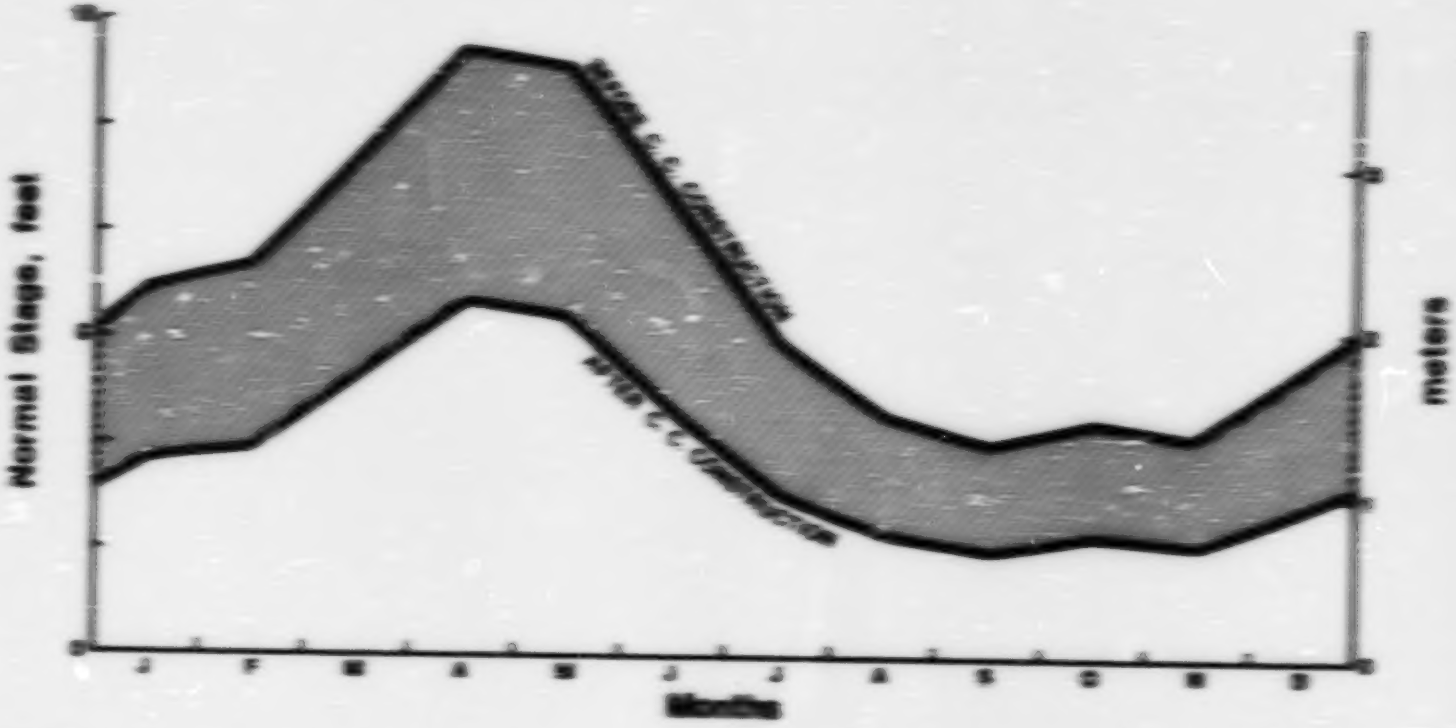

Figure 7-5. Stage hydrographs of Buffalo Cove Management Unit as calculated for present and proposed Center Channel conditions.

Table 7.1. Present and Future Averages of Water Levels, West Floodway.

	Bayou Fordoche	Cocodrie Swamp	Beau Bayou	Buffalo Cove
January				
Present	15.1	10.4	8.5	6.4
Future	7.5	4.8	4.8	3.0
Difference	7.6	5.6	3.7	3.4
February				
Present	15.7	11.2	9.3	6.8
Future	8.1	5.4	5.4	3.7
Difference	7.6	5.8	3.9	3.1
March				
Present	16.5	13.4	11.8	8.7
Future	8.9	6.9	7.4	5.0
Difference	7.6	6.5	4.4	3.7
April				
Present	17.4	15.7	14.4	10.7
Future	9.8	8.9	9.8	6.5
Difference	7.6	6.8	4.6	4.2
May				
Present	17.5	15.2	13.6	10.3
Future	9.9	7.4	9.2	6.1
Difference	7.6	7.8	4.4	4.2
June				
Present	15.6	12.2	10.6	8.0
Future	8.0	5.9	6.4	4.5
Difference	7.6	6.3	4.2	3.5
July				
Present	12.9	8.7	7.1	5.4
Future	5.8	3.9	4.0	2.6
Difference	7.1	4.8	3.1	2.8
August				
Present	12.2	7.0	5.3	4.2
Future	5.4	3.0	2.8	2.1
Difference	6.8	4.0	2.5	2.1
September				
Present	10.8	5.6	4.2	3.5
Future	4.5	2.6	2.5	1.8
Difference	6.3	3.0	1.7	1.7
October				
Present	10.9	6.2	5.0	4.0
Future	4.6	2.8	2.8	2.1
Difference	6.3	3.4	2.2	1.9
November				
Present	11.1	6.0	4.6	3.7
Future	4.7	2.7	2.7	2.0
Difference	6.4	3.3	1.9	1.7
December				
Present	12.9	8.1	6.7	5.0
Future	5.8	3.4	3.4	1.3
Difference	7.1	4.7	3.3	3.7

Present = Present mean monthly stage in feet above mean sea level.
Future = Future mean monthly stage in feet above mean sea level.

Table 7-2. Present and Future Averages of Water Levels, East Floodway.

	Bayou des Glaises	Pigeon Bay	Flat Lake	The Crevasse	Upper Belle River
January					
Present	7.7	7.4	5.0	2.8	2.8
Future	3.7	4.1	1.9	2.0	2.0
Difference	4.0	3.3	3.1	0.8	0.8
February					
Present	8.7	8.1	5.4	3.2	3.2
Future	4.2	4.6	3.2	2.2	2.2
Difference	4.5	3.5	2.2	1.0	1.0
March					
Present	11.5	10.4	7.1	4.2	4.2
Future	6.4	6.3	4.3	3.1	3.1
Difference	5.1	4.1	2.8	1.1	1.1
April					
Present	14.4	12.6	8.8	5.5	5.5
Future	9.4	8.8	5.8	4.2	4.2
Difference	5.0	3.8	3.0	1.3	1.3
May					
Present	13.5	11.9	8.3	5.2	5.2
Future	8.8	8.0	5.3	4.0	4.0
Difference	4.7	3.9	3.0	1.2	1.2
June					
Present	10.8	9.4	6.5	4.1	4.1
Future	5.8	5.4	3.8	3.0	3.0
Difference	5.0	4.0	2.7	1.1	1.1
July					
Present	6.8	6.2	4.3	2.8	2.8
Future	3.2	3.4	2.6	2.2	2.2
Difference	3.6	2.8	1.7	0.6	0.6
August					
Present	5.0	4.7	3.3	2.2	2.2
Future	2.4	2.6	2.0	1.8	1.8
Difference	2.6	2.1	1.3	0.4	0.4
September					
Present	4.0	3.8	2.8	2.0	2.0
Future	2.0	2.2	1.8	1.7	1.7
Difference	2.0	1.6	1.0	0.3	0.3
October					
Present	4.8	4.4	3.2	2.0	2.0
Future	2.3	2.5	2.0	1.6	1.6
Difference	2.5	1.9	1.2	0.4	0.4
November					
Present	4.0	4.0	2.8	1.8	1.8
Future	2.0	2.4	1.8	1.4	1.4
Difference	2.0	1.6	1.0	0.4	0.4
December					
Present	6.0	5.8	3.9	2.2	2.2
Future	3.2	3.1	2.3	1.8	1.8
Difference	2.8	2.7	1.6	0.4	0.4

Present - Present mean monthly stage in feet above mean sea level.
Future - Future mean monthly stage in feet above mean sea level.

In the previous report,[151] a method was developed to relate water levels to area and depth flooded. Use was made of a hypsometric or frequency-elevation curve; this is a curve that shows the percentage of area below a given elevation or water level. This method presently is utilized for further characterization of present and future hydrographic conditions and determination of management requirements. This characterization takes into consideration: 1) the area submerged, 2) the duration of submergence, and 3) the hydroperiod, which is a major parameter with regard to habitat.

Five hydroperiod classes, or flood duration intervals, can be distinguished when taking into consideration typical environments with regard to plant species and uses by fish and wildlife types. These classes, I-V, are presented in Table 7-3 and are related to specific habitats in terms of flooding characteristics, plant communities, and importance to fish and wildlife. The last row of the table for each class states water and related management objectives believed to be essential for maintaining the environmental quality within each of the areas synonymous with a certain hydroperiod class.

Hydrologic characterization of management units within the floodway can now proceed for three conditions: 1) present, 2) resulting at implementation of the proposed Center Channel, and 3) managed according to the objectives stated in Table 7-3. The Pigeon Bay Management Unit is utilized as an example and will be discussed in reference to Figure 7-6. For all other management units, the hydrologic information is depicted in an identical manner in Figures 7-7 through 7-14.

Present conditions in Pigeon Bay (Figure 7-6) are described by the two curves giving absolute elevation of the land surface (Curve D) and present average annual variation of water levels (Curve B). Using the left-hand and bottom scales, the hypsometric curve (D) shows the percentage of the total area that lies below a given elevation, or the percentage of the total area that is flooded when water level attains a given elevation. For example, the present average hydrograph (B) shows maximum water level to occur in April at 4 m (13 ft) MSL. At that level, 86% of the Pigeon Bay Management Unit will be flooded, as indicated by the dashed line a - b - c.

In the above manner, it can also be determined what percentage of the area is presently flooded for a given period of time; that is, what percentage of the management unit experiences a given hydroperiod. For example, to determine what percentage presently experiences a 4- to 8-month hydroperiod (Class III), horizontal lines equivalent to 4- and 8-month periods, respectively, are fitted under the hydrograph (B). In Figure 7-6, position of the line corresponding to the 4-month hydroperiod for present conditions is found using the right-hand scale (present). The line segment d - e is equivalent to a 4-month period. Its

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[151] Coastal Environments, Inc., 1974a, *op. cit.*

Hydroperiod Class Interval	Class I [illegible]	Class II [illegible]	Class III [illegible]	Class IV [illegible]	Class V [illegible]
Flooding Characteristics	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Plant Communities	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Importance to Fish and Wildlife	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Management Objectives	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 7-1. Relationship between flooding characteristics and biological conditions and values.

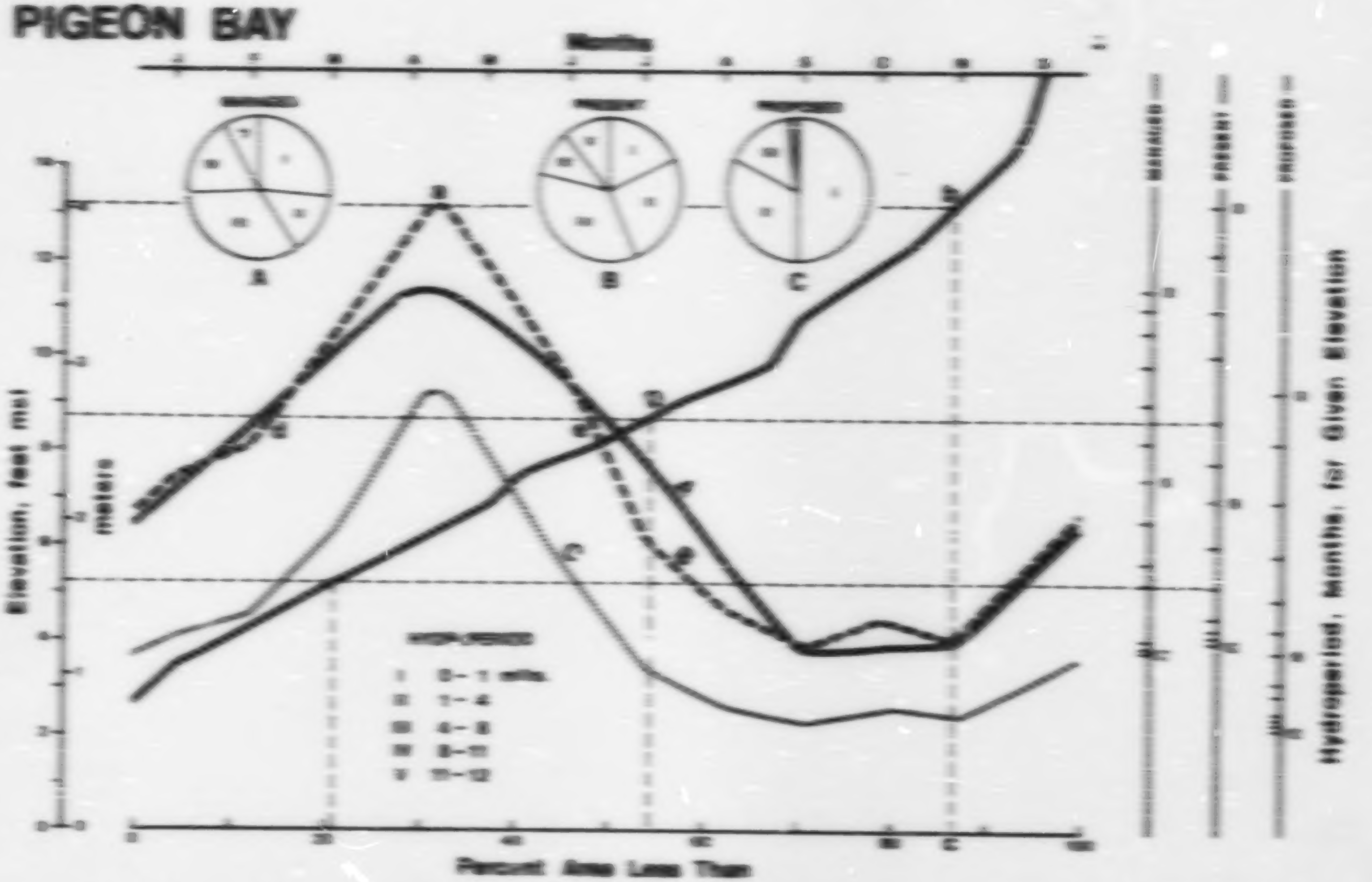

Figure 7-6. Flooding characteristics of Pigeon Bay Management Unit. Stage hydrograph curves show annual water level changes for desirable managed (A), present (B), and proposed Center Channel (C) conditions. Curve D gives cumulative frequency occurrence of elevations. Pie-graphs show relative size of areas subject to given hydroperiod class (Table 7-2) under conditions A, B, C.

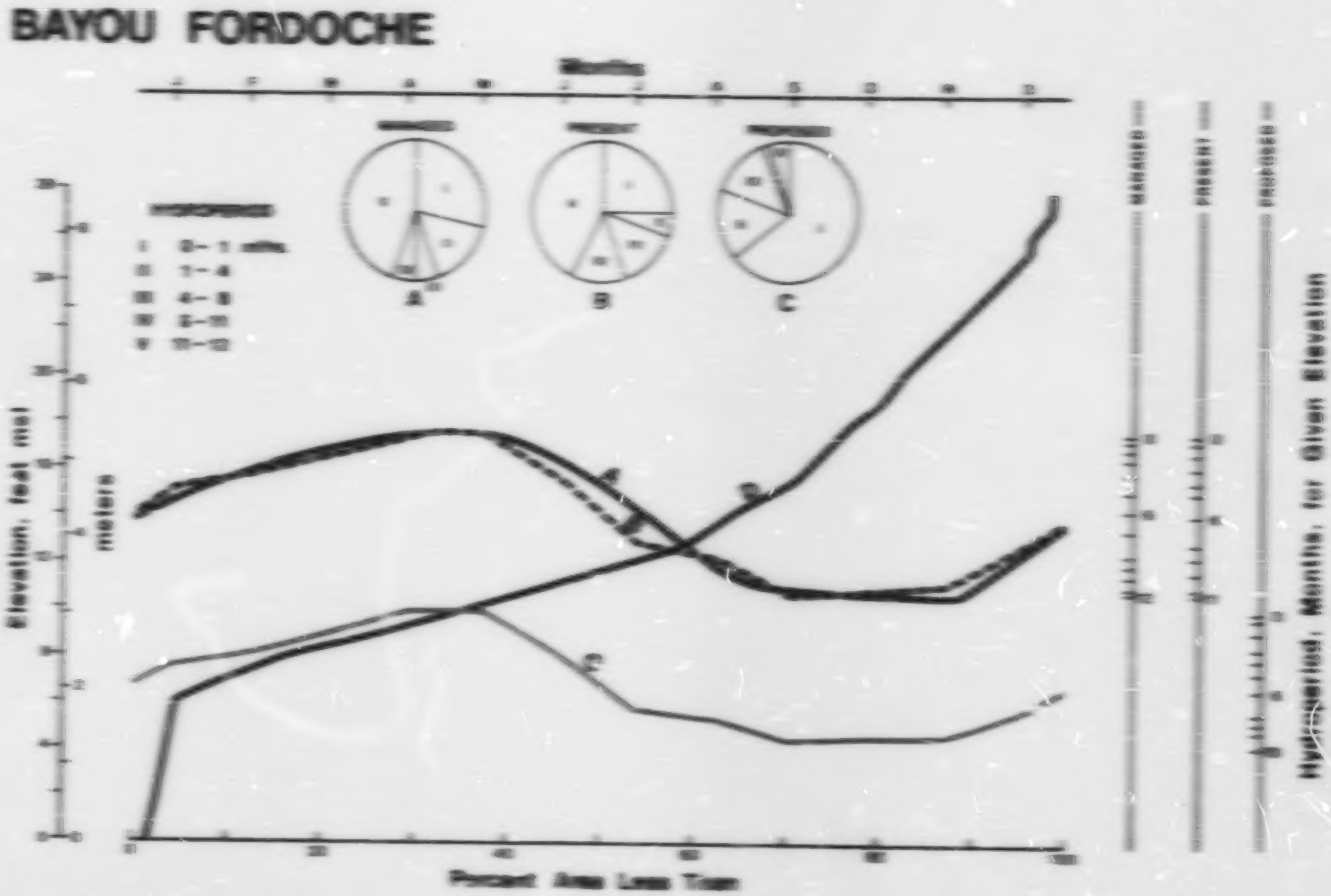

Figure 7-7. Flooding characteristics of Bayou Fordoche Management Unit.

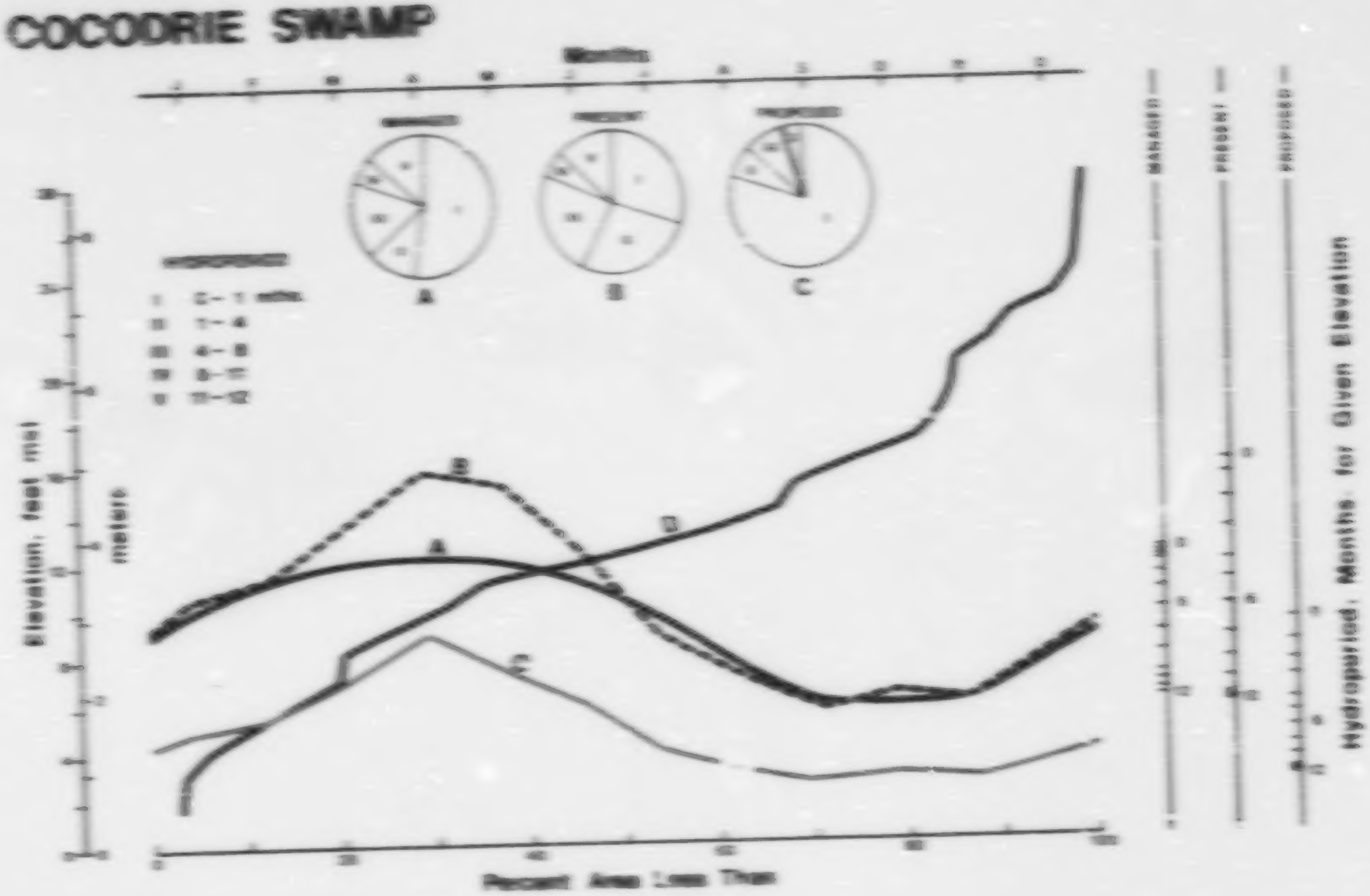

Figure 7-6. Flooding characteristics of Cocodrie Swamp Management Unit.

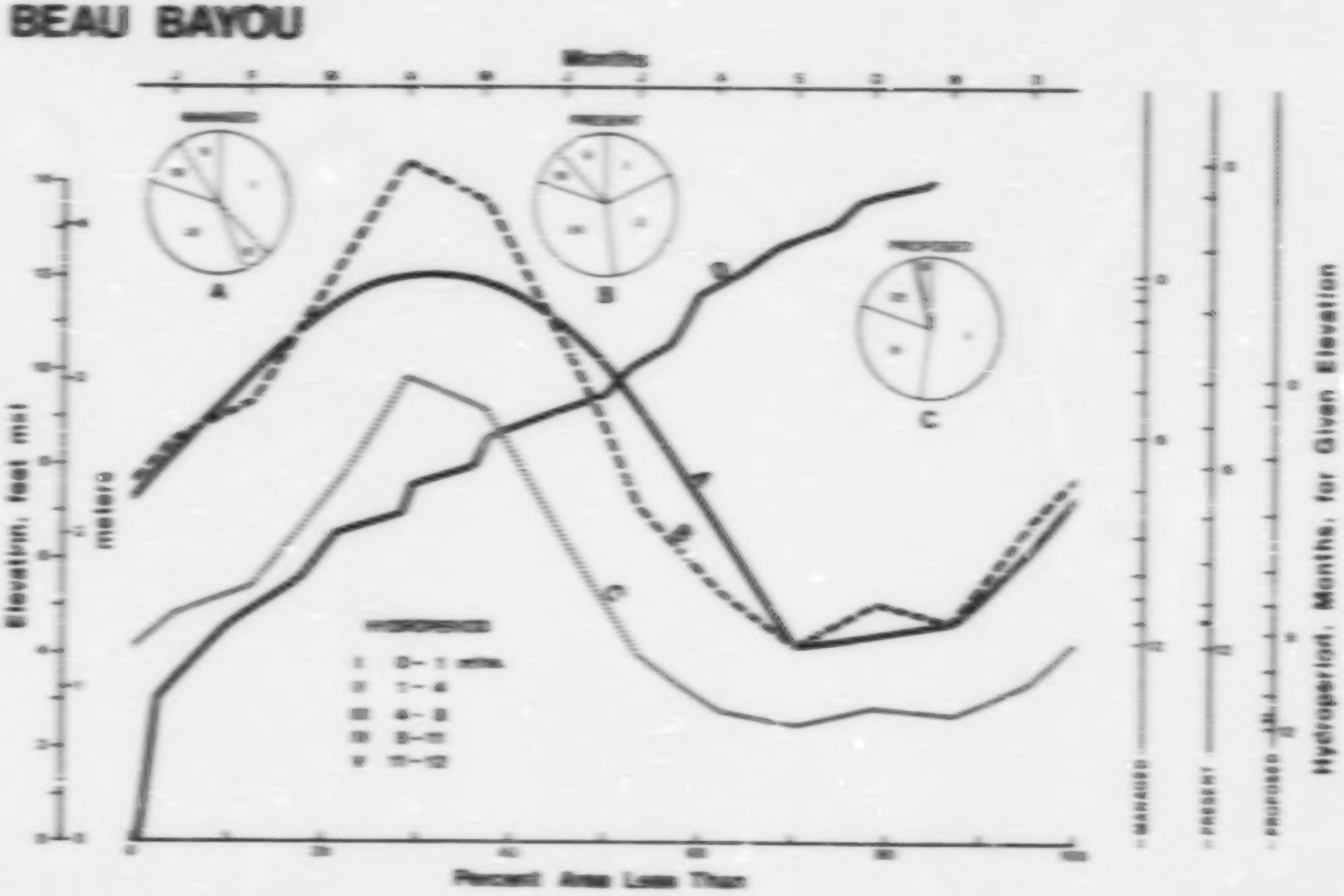

Figure 7-4. Flooding Characteristics of Beau Bayou Management Unit.

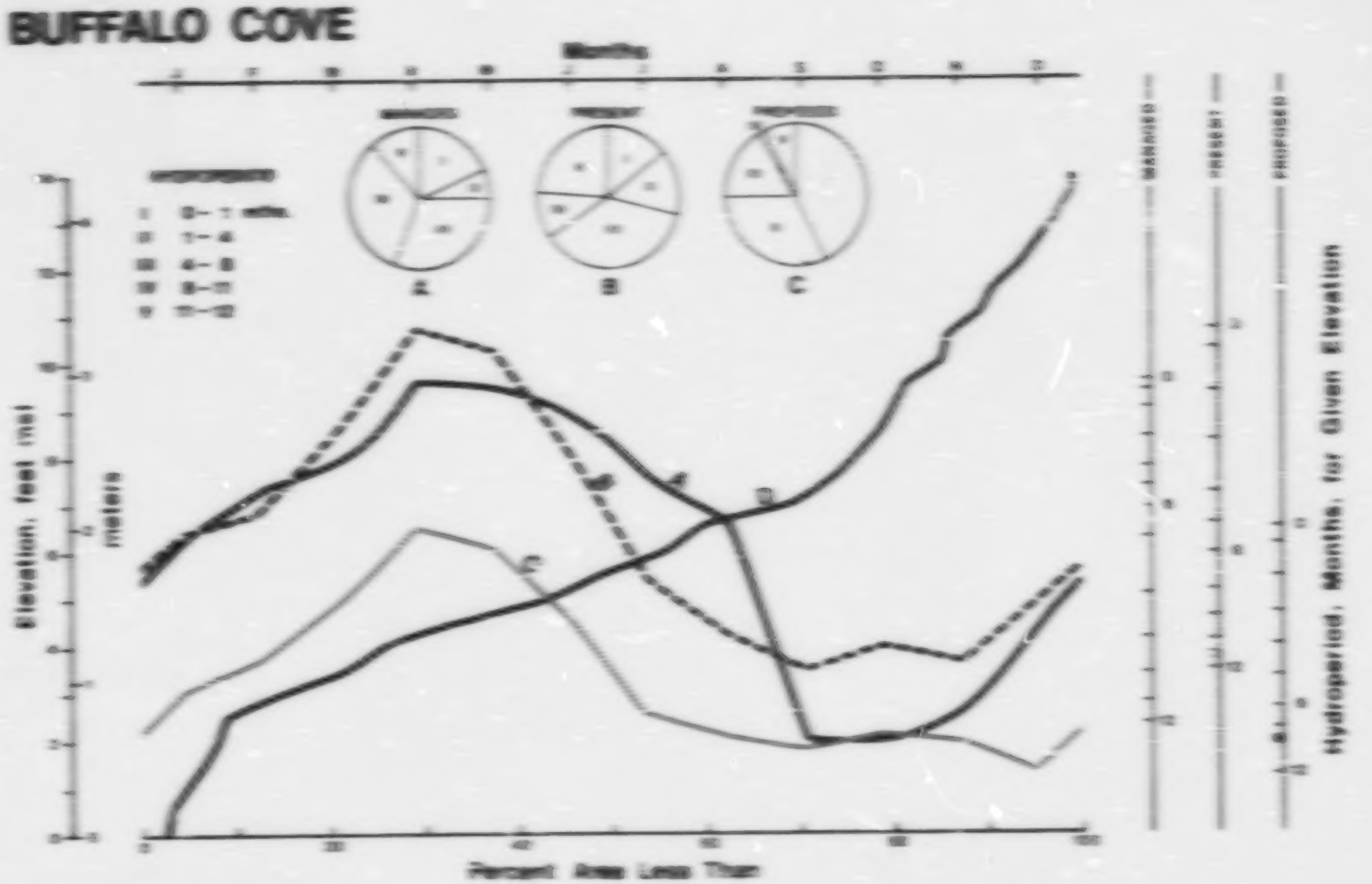

Figure 7-22. Flooding Characteristics of Buffalo Cove Management Unit.

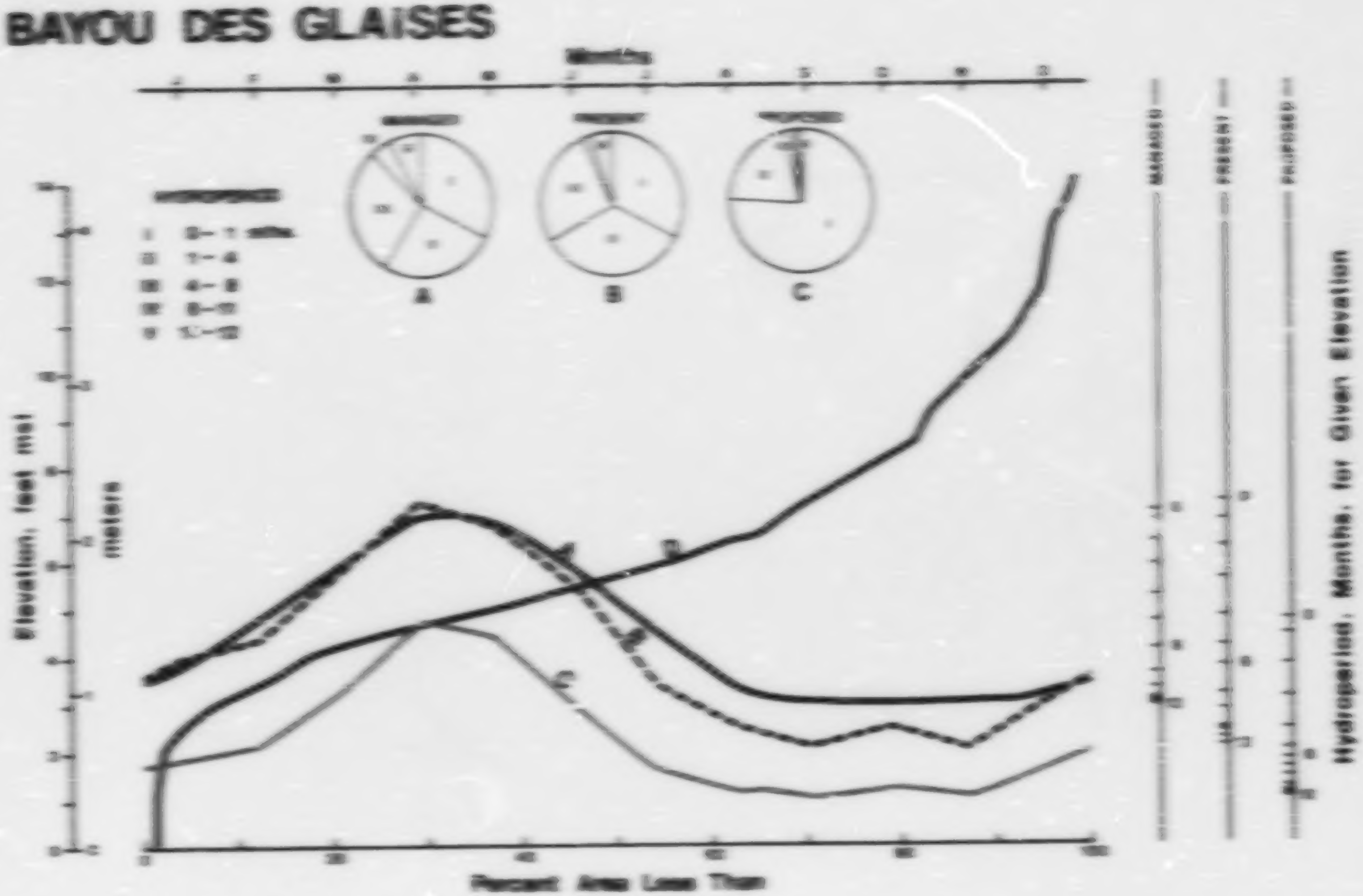

Figure 7-11. Flooding Characteristics of Bayou Des Glaises Management Unit.

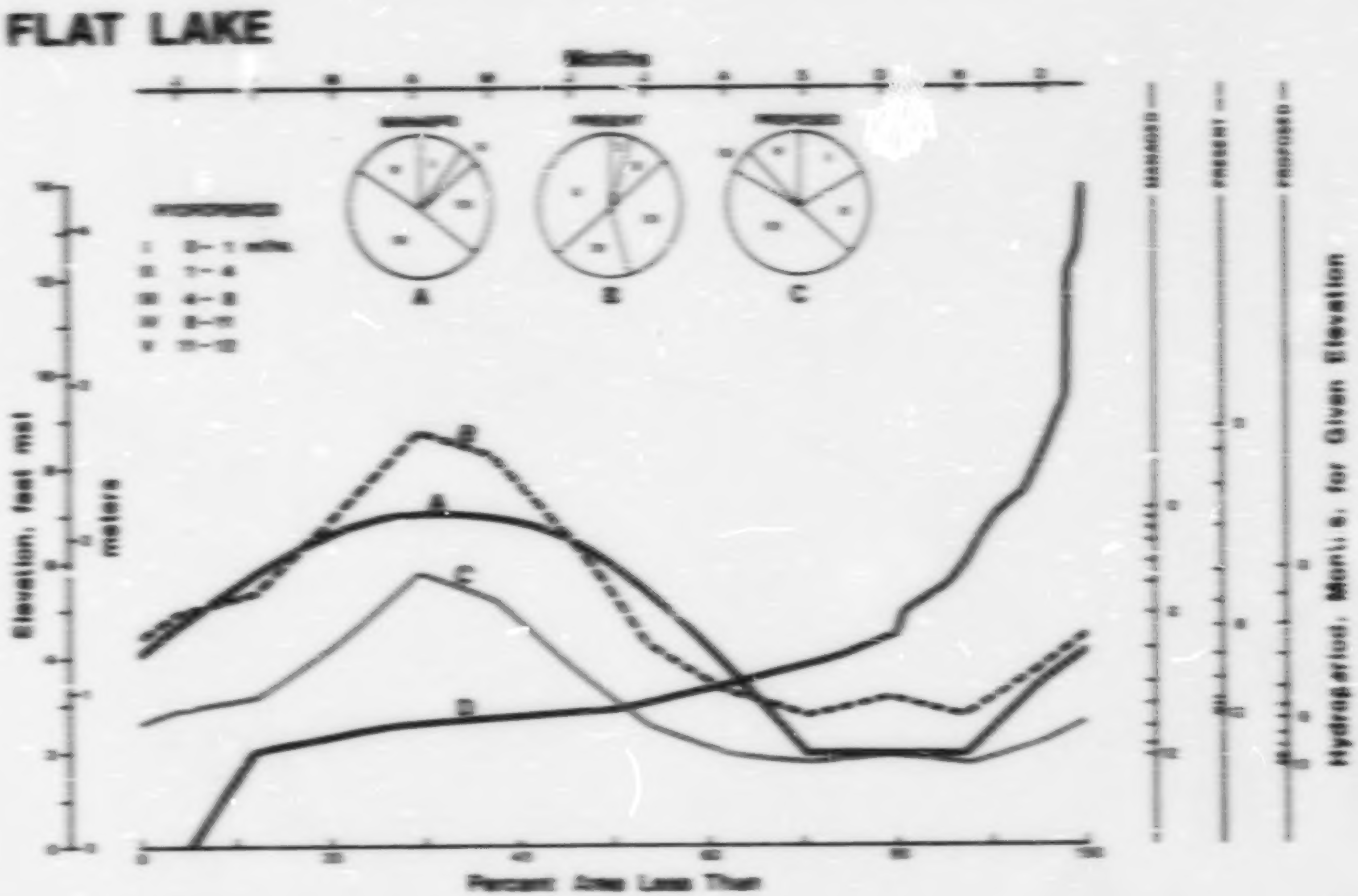

Figure 7-22. Flooding Characteristics of Flat Lake Management Unit.

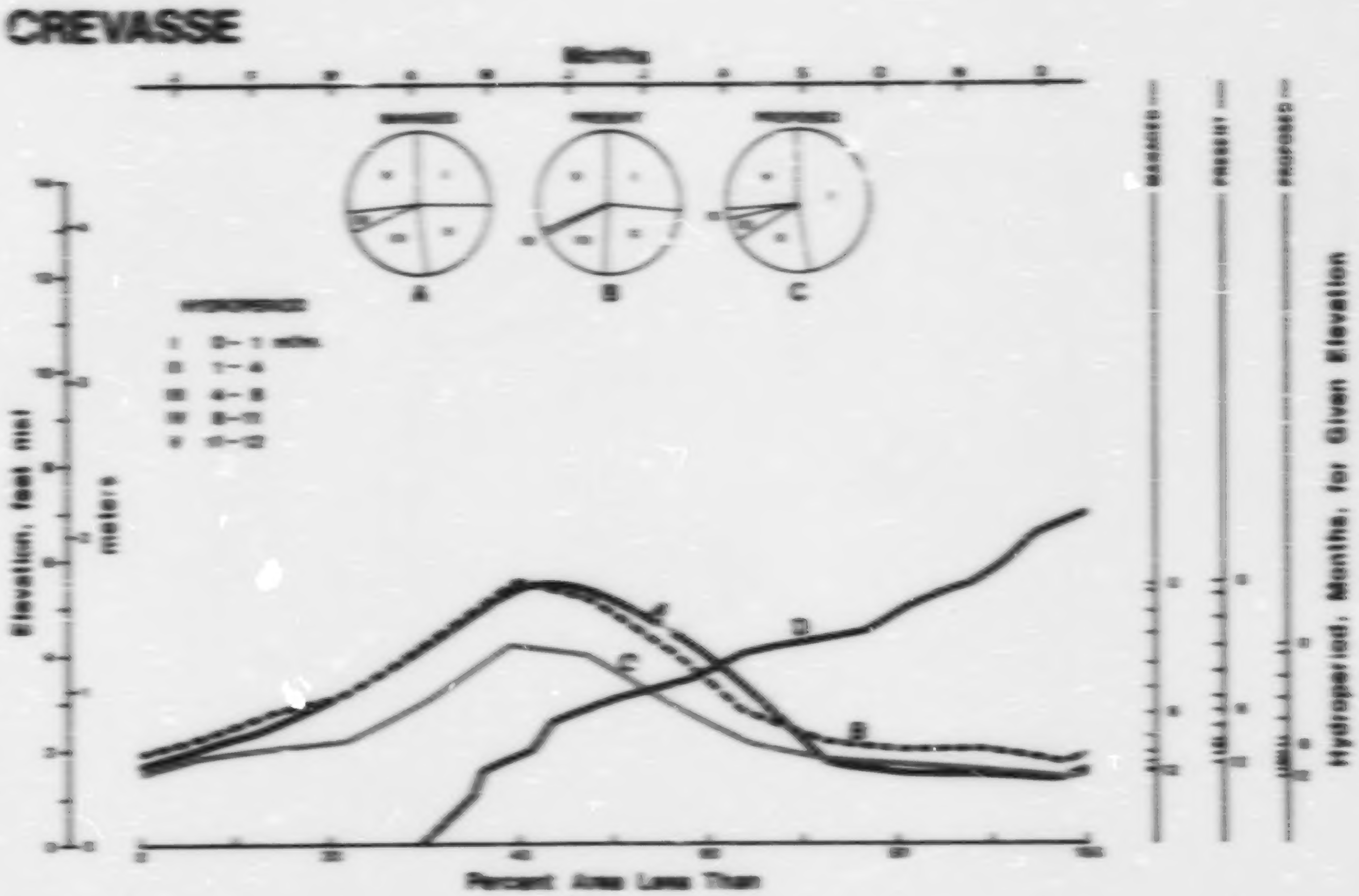

Figure 7-13. Flooding Characteristics of Crevasse Management Unit.

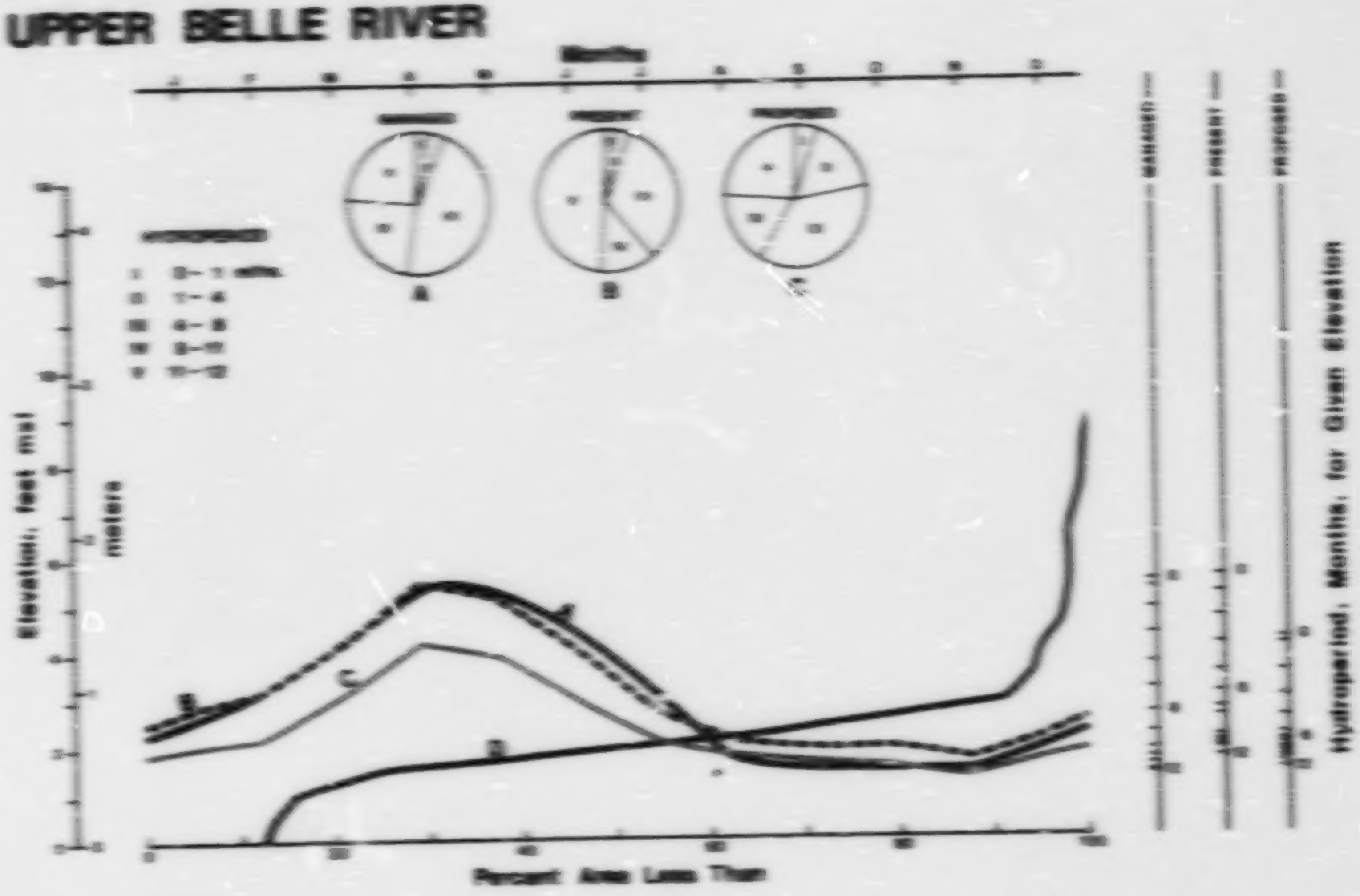

Figure 7-3A. Flooding Characteristics of Upper Belle River Management Unit.

position shows that 2.7 m (8.7 ft) MSL (left-hand scale) is the elevation below which flooding occurs for four or more months. Using the earlier-described procedure involving the hypsometric curve, it can thus be seen that 54% of the management unit experiences submergence for a period equal to, or in excess of, four months. Likewise, it is determined that 21% experiences flooding during eight or more months. Thus, it can be said that a four- to eight-month hydroperiod is experienced by 54 minus 21, or 33%, of the Pigeon Bay Management Unit, located between elevations of 2.7 m (8.7 ft) and 1.6 m (5.2 ft) MSL.

In the above-described manner, percent area is also determined for the other four hydroperiod classes (I, II, IV, and V), after which the information is summarized in Pie-graph B (Figure 7-6). Similarly, percentages are obtained for the desirable managed (A) and proposed Center Channel (C) conditions, respectively, and expressed in pie-graph form.

Having obtained the area of each of the management units, percentages can be converted into actual areal dimensions. This information is summarized for each of the management units and hydroperiod classes in Table 7-4. The examined condition for Pigeon Bay related to a hydroperiod of four to eight months under present conditions is seen to apply to 59 km². The area of the entire Lower Atchafalaya Floodway presently experiencing such conditions is 541 km², with the largest occurrence in the Upper Belle River Unit. Center Channel conditions are seen to decrease this area to 415 km². Tabulated data further show that managed conditions would favor the eight-month to eleven-month hydroperiod.

So far, the third, or managed, condition as shown in Figure 7-6 has been ignored, insofar as it concerns criteria used to arrive at the management hydrograph. The curve labeled "A" is a hydrograph that is considered to represent desirable conditions from a point of view that takes jointly into consideration fish and wildlife requirements, forestry requirements, and commercial fisheries requirements. Thus, management objectives as applied in the present case are not weighted toward a particular species, but toward management for diversified subsystems as they presently exist, with emphasis on the use of renewable resources and abatement of present deterioration.

A number of steps were taken to arrive at the management hydrograph. The first step is related to the high water level. In this regard, it should be pointed out that water level is in some way proportional to sediment input. Raising water levels in a sub-basin above a given stage requires input of sediment-laden river water. With overbank flooding largely prevented, influx of sediment-laden water must be considered to have detrimental impact. It can, therefore, be reasoned that inflow and water level should not exceed the minimum that will sustain, or preferably enhance, present natural resource values. From that vantage point, minimally required high water

Table 7-4. Areas subject to given hydroperiod class (Table 7-3) within floodway management units for managed, present, and proposed conditions respectively

	Beau Bayou	Cocodrie Swamp	Bayou Postillion	Bayou des Glaises	Pigeon Bay	Flat Lake	L. Belle River	Henderson	Buffalo Cove	Totals
mi² – HYDROPERIOD I										
Managed	32	81	79	86	41	18	23	30	44	429
Present	26	47	80	84	29	9	23	17	36	346
Proposed	46	123	207	296	76	18	25	66	102	889
mi² – HYDROPERIOD II										
Managed	3	19	11	67	24	6	15	34	15	195
Present	25	42	15	88	42	13	21	35	34	315
Proposed	24	13	52	22	48	39	87	27	74	426
mi² – HYDROPERIOD III										
Managed	38	23	32	79	58	41	220	30	12	488
Present	28	15	48	72	52	38	160	25	85	561
Proposed	24	13	45	5	26	82	179	8	41	425
mi² – HYDROPERIOD IV										
Managed	5	9	15	5	25	66	128	6	16	274
Present	6	9	18	8	16	33	65	2	27	185
Proposed	1	1	3	1	1	4	86	4	1	105
mi² – HYDROPERIOD V										
Managed	9	22	142	19	12	38	222	37	29	421
Present	18	22	137	8	15	86	261	43	36	629
Proposed	2	6	12	4	2	21	223	37	18	326

levels are determined for each management unit taking into consideration their present topography and characteristics, requirements of principal fish and wildlife species, and small boat requirements for commercial and sport fisheries.

The second step relates to the low water level. The three principal considerations are necessary dewatering as a crawfish production requirement, providing surface exposure to the atmosphere to allow decay of organic matter for water-quality enhancement, and the need to maintain sufficient water depth over a large enough area to serve as a collection basin for fishes dispersed throughout the flooded swamp during preceding high-water stages. One guideline toward selection of the minimum water level is the knick point at the lower end of the hypsometric curve. The hypsometric curve segment to the left of this point represents predominantly the area occupied by lakes, channels, and canals within the sub-basin. As a minimum, this area needs to remain flooded. Based on examination of present conditions in a number of management units, the area flooded at minimum stages should not be less than 5% of the management unit area, while it is desirable to maintain more.

A third step relates to the shape of the hydrograph within the constraints of a minimum and maximum water-level. On the basis of present conditions and fisheries requirements, water-level variation should follow as closely as possible the present river-stage regime, with a general rise beginning in November, a peak by March/April, and a low water stage from September through October. However, where desired maximum and minimum water levels deviate from present conditions and more efficient utilization of local runoff is desirable to minimize needed river water input, control is necessary over inflow and outflow into and from the management units. Such controls affect rates of water-level rise and fall and, therefore, shape of the hydrograph, to some extent.

A hydrograph for managed conditions in which inflow and outflow were controlled was obtained for the Buffalo Cove Management Unit in a previous study.[152] Taking into account monthly precipitation surpluses, desired maximum and minimum levels, storage volume of the unit, feasible size of the inlet and outlet channels, and monthly water levels inside the sub-basin and in surrounding supply channels, resulting flow rates and monthly water levels during the periods between maximum and minimum stages were calculated. The hydrograph thus obtained is the one shown and labeled A in Figure 7-10. The hydrograph deviates from the present regime mainly during falling stage when water levels are higher than at present during July and August. This deviation relates mainly to stage difference inside and outside the sub-basin controlling the rate of drainage. Increasing the size of the outlet channel reduces this channel only slightly.

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[152] Coastal Environments, Inc., 1974b, op cit.

Results of the above study were utilized in the present study to define the general shape of the management hydrographs for all units in terms of rate of flooding and dewatering. Within the constraints of the determined maximum and minimum stages, the management hydrographs in Figures 7-7 through 7-14 represent an approximation of water-level change expected to prevail under managed conditions where sub-basin inflow and outflow are controlled.

To further evaluate changes resulting from the three conditions -- managed, present, and proposed -- maps can be prepared showing distribution of the areas experiencing a specific hydroperiod interval. This can be done on the basis of topography, having obtained the relationship between elevation and hydroperiod through Figures 7-6 to 7-14. As an example, such distributions were developed for the Pigeon Bay Management Unit and are shown in Figures 7-15, 7-16, and 7-17. Comparison of the maps shows a close resemblance between managed and present conditions. The main change is an increase in the area experiencing up to a 1-month hydroperiod at the expense of the 1- to 4-month hydroperiod area. A slight gain is registered relative to present conditions for the area having a hydroperiod of 8 to 11 months. Much more severe are the changes related to proposed Center Channel conditions. Permanent water bodies are partially converted to the 8- to 11-month hydroperiod. The entire area presently experiencing a Class IV hydroperiod is reduced to 4 to 8 months. In general, one notices for all areas a shift to the next lesser hydroperiod and a major increase of the area flooded for one month or less.

Water Balance, Yield, and Storage

One prerequisite to determining water-management options for the Atchafalaya Basin, and in particular for the floodway swamp environments with or without the proposed Center Channel, is an evaluation of potential water supply. Previous sections dealt predominantly with the Atchafalaya River as a variable water source. Through analysis of the water balance, the present section attempts to evaluate precipitation yield within the Atchafalaya Basin Floodway as a manageable resource. It should be pointed out, however, that inherent to data and time limitations, quantitative results presented here should be considered approximate and subject to further refinements through use of more advanced and time-consuming analysis.

The first step in the evaluation of water yield within the Atchafalaya Basin is the determination of amounts of rainfall, evapotranspiration loss, soil storage, and runoff at various points in the basin. Data from the previous study,[153] utilizing the Thornthwaite - Mather water-balance method, were available for this purpose. These data are in two forms of computer printout. One form provides monthly

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[153] Coastal Environments, Inc., 1974a, *op. cit.*

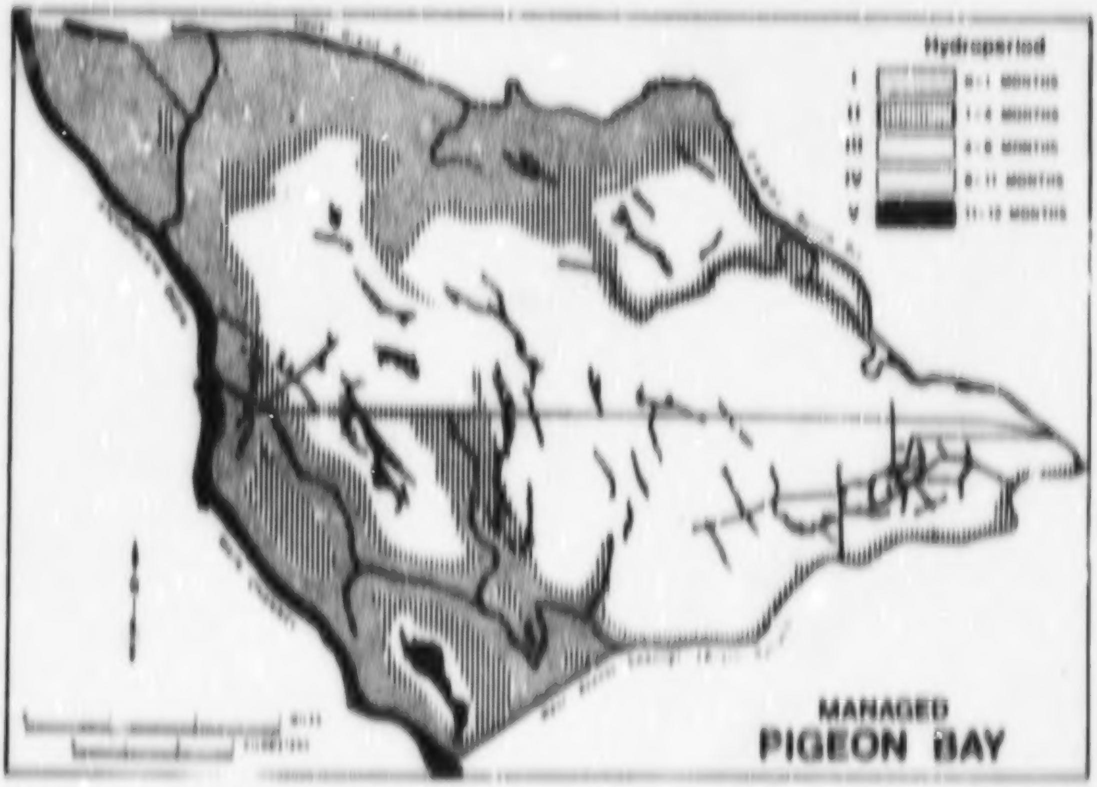
Hydroperiod
I 0-1 MONTHS
II 1-4 MONTHS
III 4-8 MONTHS
IV 8-11 MONTHS
V 11-12 MONTHS
MANAGED
PIGEON BAY

Figure 7-15. Distribution and size of areas subject to given hydroperiod class (Table 7-3) under managed conditions in Pigeon Bay Management Unit.

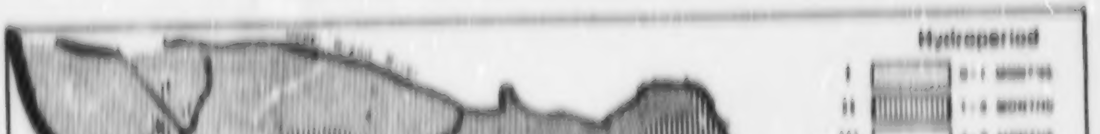
Hydroperiod
I
0 - 1 MONTHS
II
1 - 4 MONTHS
III
4 - 8 MONTHS
IV
8 - 11 MONTHS
V
11 - 12 MONTHS
PRESENT
PIGEON BAY

Figure 7-16. Distribution and size of areas subject to given hydroperiod class (Table 7-3) under present conditions in Pigeon Bay Management Unit.

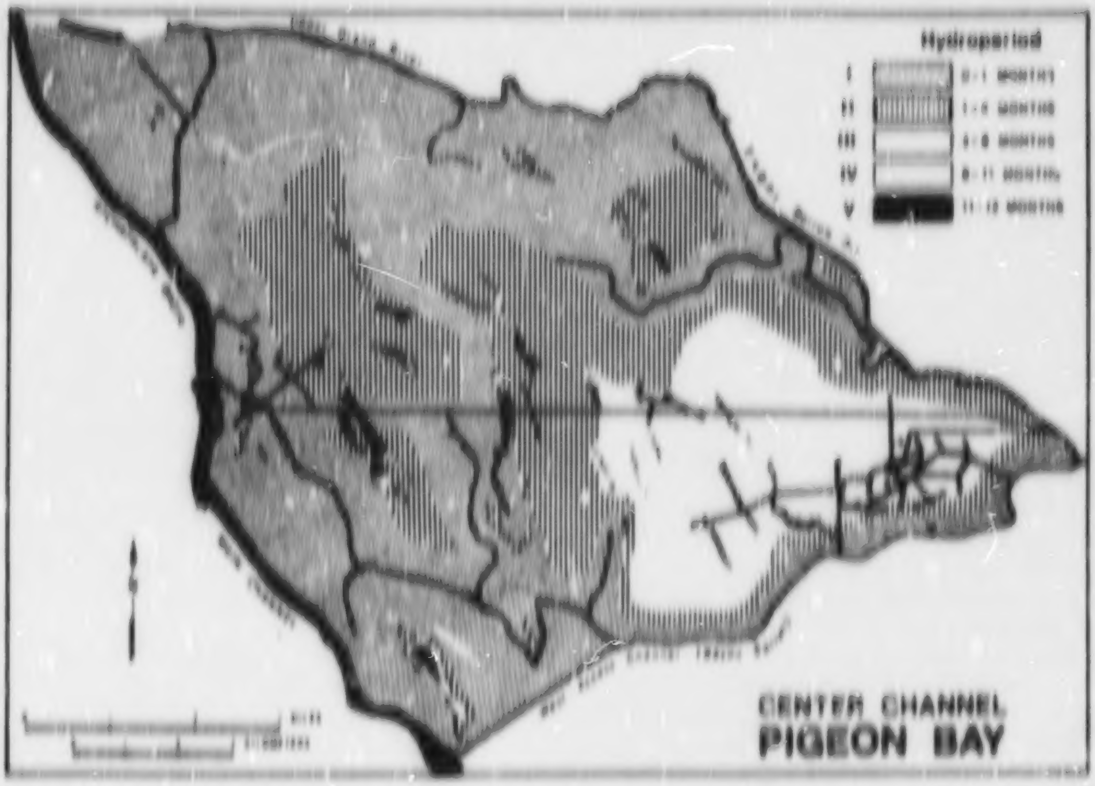
Hydroperiod
I 0-1 MONTHS
II 1-3 MONTHS
III 3-6 MONTHS
IV 6-11 MONTHS
V 11-12 MONTHS
CENTER CHANNEL
PIGEON BAY

Figure 7-17. Distribution and size of areas subject to given hydroperiod class (Table 7-3) under proposed center channel conditions in Pigeon Bay Management Unit.

values from 1945 through 1968 of all elements of the water balance at every long-period climatological station in or close to the basin. The second form provides data for the same period of net gains or losses of moisture over 10,000-foot square cells within the basin. These latter calculations were based on fixed land-water ratios in each cell determined by examination of topographic maps.

It was decided to use the station water-balance data for deriving water yield. Two factors were considered in this decision. One was the discovery during a special study of the Buffalo Cove Management Unit[154] that water losses from a water hyacinth cover can greatly exceed the potential evapotranspiration (PE) rate. Water hyacinths abound in the Atchafalaya Basin Floodway, and it is necessary to make separate evaluations of land evaporation, open water evaporation, and evapotranspiration from surfaces covered by water hyacinth plants. As in the previous study, open water and non-hyacinth-covered swamps are grouped together and assumed to lose moisture at the PE rate.

The second factor involved in the choice of data is the variation in water level of inundated areas. This matter has been discussed in the previous section, but it should be pointed out that water levels in the winter and spring and the associated increase in flooded land surface during that period cause a corresponding increase in area-wide evaporation loss. Therefore, use of a fixed land-water ratio, although acceptable on a long-term basis, results in overestimates of water yield during the winter and spring months and underestimates during the remainder of the year.

The climatological stations used in the water-balance analysis are the same as those utilized in the previous study.[155] Records for these stations were processed by computer to determine monthly values of precipitation (P), potential evapotranspiration (PE), and precipitation surplus over land areas (S); P-PE then represents moisture gain over wetlands, and S represents moisture gain or runoff over the dry-land portion of the area. A third component, moisture gain over that portion of the area covered by water hyacinths, remains to be determined.

There is evidence of abnormally high water losses in areas of large concentrations of water hyacinths, such as the Buffalo Cove unit. However, the only quantitative data bearing on this problem are a series of lysimeter measurements in the Gulf coastal region made by Penfound and Earle in June and July, 1946,[156] and by Timmer and Weldon from April to September, 1967.[157] The measured evapotranspiration from water hyacinths in these experiments is plotted against PE computed from meteorological records in Figure 7-18. There is a wide scatter of points in the graph, probably due to factors such as wind, humidity, and cloudiness, not taken into account in the Thornthwaite formula. However, the rates of measured losses (ET) are consistently higher than PE calculated for the same conditions (see free-water evaporation, Figure 7-18) and are generally much greater.

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[154] *Ibid.*

[155] *Ibid.*

[156] Penfound and Earle, 1948, *op. cit.*

All of the lysimeter tests plotted in Figure 7-18 were made during the warm season of the year. A reasonable assumption is that at the lower end of the scale, reflecting the dormant season, ET should approximate open-water evaporation, or PE. Therefore, a curve was drawn defining the relationship between the water hyacinth loss rate and the PE rate through the centroid of plotted points of Figure 7-18 and asymtotic to open-water evaporation rate at the lower end. This curve was used to estimate monthly values [illegible] evapotranspiration from water hyacinth cover and thereby complete the water-balance calculation. The bar diagram of Figure 7-19 illustrates this calculation for the station at Jeanerette, Louisiana. This diagram is based on 26-year averages and indicates the probable presence of long-term water deficits in areas covered by water hyacinths as opposed to net water-yield from other types of surface cover.

As discussed in the previous paragraph, three types of surface cover were distinguished in the determination of net gain or loss of water from a given area. These are dry-land surface, non-hyacinth-covered wetland, and water hyacinth-covered wetland. The relative proportion of each type of cover is therefore an important factor in the determination of net water-yield from a management unit. The amount of dry-land area is a function of water level and topography and can be obtained by the procedure described earlier. The extent of water hyacinth was estimated from examination of recent aerial photographs of the floodway taken by NASA, supplemented by gross estimates furnished by the Louisiana Wild Life and Fisheries Commission. The results are summarized in Table 7-5.

The formula applied in the computation of water yield on a unit-wide basis is as follows:

$$Y = 0.8314R(1 - WS) + (1 - WH)(P - PE) + WH(P - ET)WS,$$

where Y is water yield in inches, R is land runoff in inches, P - PE is gain or loss of water from the non-hyacinth water surface in inches, P - ET is gain or loss of water from the hyacinth-covered water surface in inches, WS is the ratio of water surface to total area of the unit, and WH is the ratio of water hyacinth-covered area to water-surface area. The coefficient of the first term on the right-hand side of the

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[157] Timmer and Weldon, 1967, op. cit.

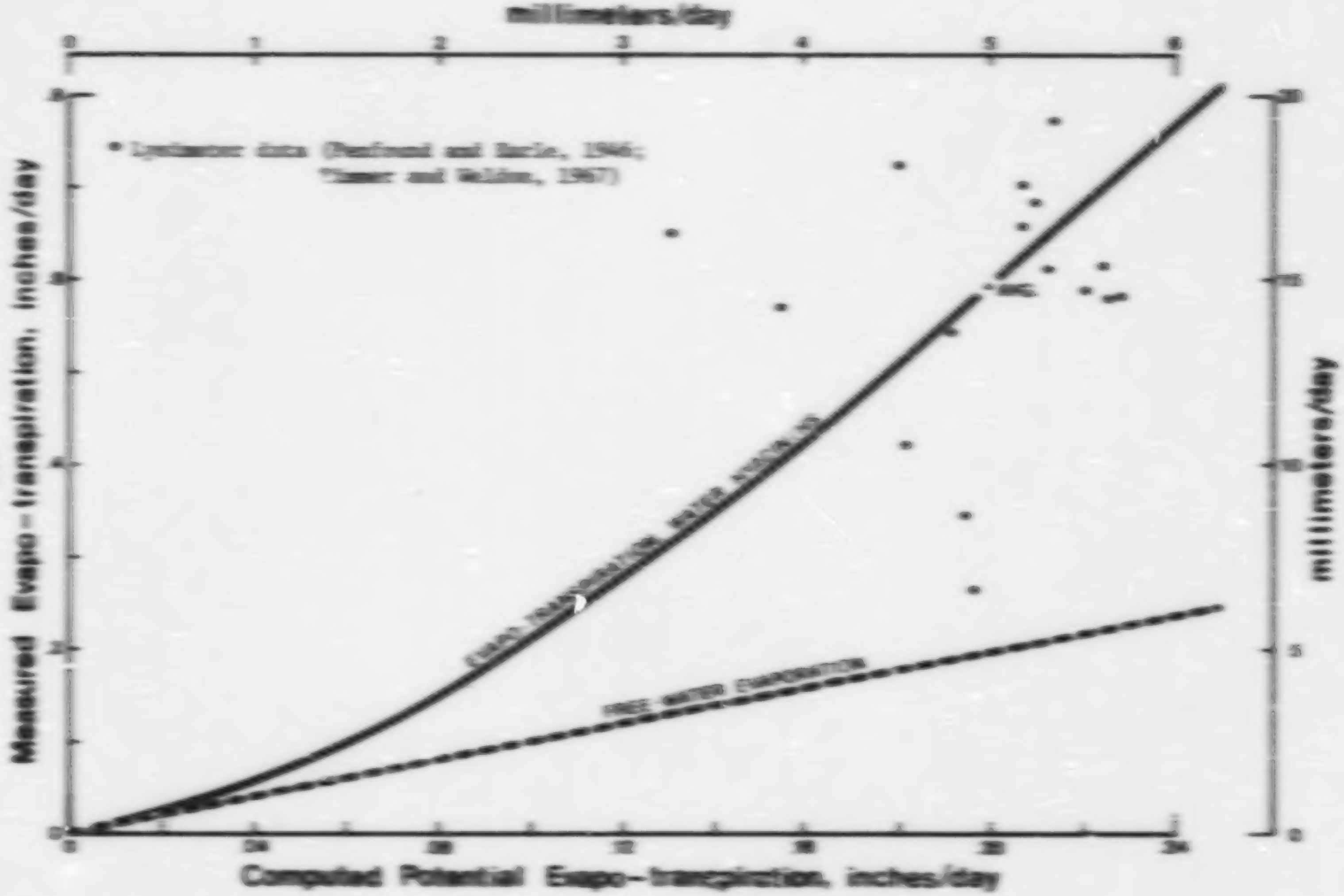

Figure 7-18. Evapotranspiration from a free-water surface and a hyacinth covered surface, respectively

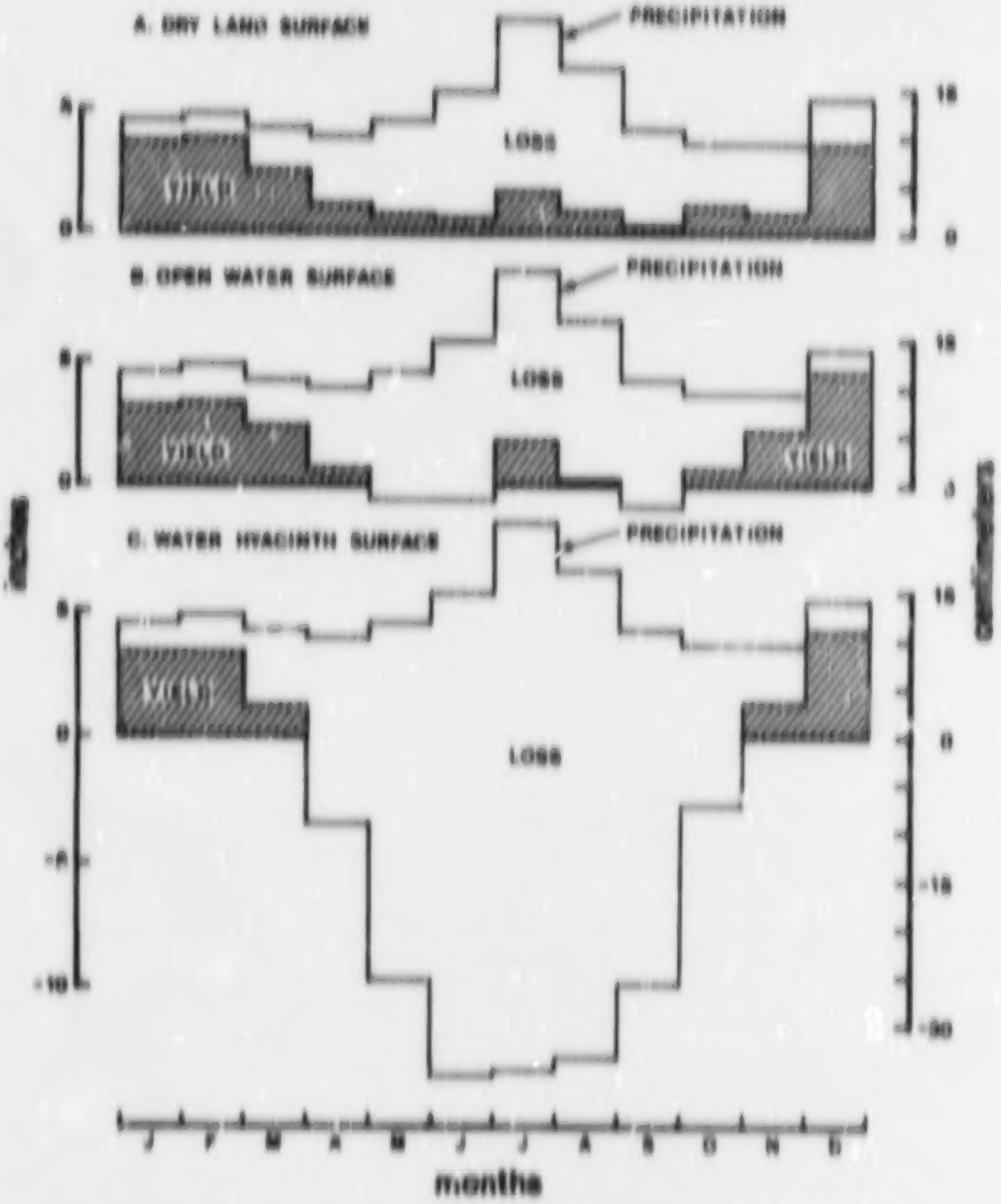

Figure 7-19. Water balance illustrating difference in water yields and losses for land surface, open-water surface, and hyacinth-covered water surface, respectively.

Table 7-5. Pertinent Data, Water Management Units.

	SYM	AREA (MI^2)	Water Hyacinth Coverage (%)
West Floodway	W1	211	.05
Bayou Fordoche	W2	123	.10
Warner Lake	W3	34	.15
Cocodrie Swamp	W4	60	.15
Beau Bayou	W5	33	.15
Buffalo Cove	W6	91	.40
Six Mile Lake	W7	48	.05
Morganza Floodway	E1	99	.05
Alabama Bayou	E2	77	.10
Bayou des Glaises	E3	100	.15
Pigeon Bay	E4	59	.15
Flat Lake	E5	70	.10
The Crevasse	E6	55	.05
Upper Belle River	E7	192	.15

equation is the land-runoff adjustment factor obtained by correlation with observed streamflow, as described in an earlier report.[158]

Volume of water yield in million cubic feet is a more convenient unit for water-management calculations and is obtained by means of the following conversion formula:

$$V(MCF) = V(INCHES)\ A\ (SQ.\ MILES)\ 2.3232,$$

where A is the total area of the management unit.

An example of a water-yield computation is shown in Table 7-6 for the Buffalo Cove Unit. Normal monthly values of yield are computed utilizing water-balance data derived for the Jeanerette, Louisiana, station. The area of the unit is 236 km^2 (91 mi^2), and water hyacinth coverage was estimated to be 40%. Similar data were developed for the other units, and the results are summarized in Tables 7-7 and 7-8.

Previous discussion of basin hydrology revealed a major reduction of water levels and aquatic habitat as a result of Center Channel construction. Diminution of this effect would require measures to retain water within the management units and/or introduction of supplemental water. Likewise, any replacement of required river-water inflow by precipitation surplus as a measure to reduce siltation would call for water storage. Storage characteristics of individual management units for specific water levels are therefore a major concern.

The hypsometric curve of the management unit forms the basis for determining the capacity of that unit to store water. The integrated area between agiven water-surface elevation and a minimum reference elevation, shown diagrammatically in Figure 7-20, multiplied by a scale factor, provides the storage content for that particular water level. A series of these values, computed and plotted from minimum to maximum elevation, forms the storage-elevation curve for the unit. Utilizing individual hypsometric curves, storage-elevation curves were determined for the lower nine floodway management units dominated by swamp habitat. These curves are shown in Figures 7-21 and 7-22 for the units to the east and west of the Main Channel, respectively. Differences in steepness between the curves reflect the increase in ground slope toward the north.

The storage curve allows determination of the volume of water required to raise the water level in a managed unit to the desired level, or conversely, of the volume released when the water level falls to a given stage. It is an indispensable tool in determining water needs to fulfill management requirements and will be further applied in subsequent sections dealing with plan development.

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[158] Coastal Environments, Inc., 1974a, *op. cit.*

Table 7-6. Water-Yield Computation, Buffalo Cove Management Unit.

	S	P-PE	P-ET	ST/GR	WS	YIELD INCHES	YIELD MCF
January	3.60	3.63	3.86	6.4	.59	3.30	699
February	3.81	3.77	3.37	6.8	.65	3.46	730
March	2.52	2.36	1.07	8.7	.79	1.89	399
April	1.17	0.58	-3.49	10.7	.87	-0.98	-208
May	0.81	-0.55	-9.31	10.3	.86	-3.39	-717
June	0.63	-0.62	-13.53	8.0	.76	-4.27	-903
July	1.73	1.70	-13.33	5.4	.47	-1.26	-267
August	0.86	0.19	-12.91	4.2	.29	-0.96	-203
September	0.27	-0.90	-9.94	3.5	.22	-0.82	-173
October	1.11	0.64	-2.72	4.5	.27	0.48	102
November	0.76	2.12	1.35	3.7	.23	0.90	191
December	3.63	4.51	6.88	5.0	.43	3.60	762
TOTAL	20.90	17.41	-51.89			1.95	413

Table 7-7. Normal Monthly Water Yield in Million Cubic Feet, Management Units in West Side of Floodway.

			Units*		
Month	W1	W2	W4	W5	W6
January	2026	1148	478	266	699
February	1863	1163	502	282	730
March	1333	749	326	180	399
April	950	246	67	27	-208
May	742	-63	-104	-75	-717
June	167	-577	-182	-122	-903
July	108	-198	60	23	-267
August	0	-380	-16	1	-202
September	4	-283	-29	-3	-173
October	86	-31	62	35	102
November	408	396	131	62	191
December	1050	984	423	236	762
Total	9050	3154	1710	912	413

*W_1 = West Floodway
W_2 = Bayou Fordoche
W_4 = Cocodrie Swamp
W_5 = Beau Bayou
W_6 = Buffalo Cove

Table 7-8. Normal Monthly Water Yield in Million Cubic Feet, Management Units in East Side of Floodway.

Month	E1	E2	E3	Units* E4	E5	E6	E7
January	652	950	815	242	577	570	1589
February	680	874	868	471	650	525	1708
March	461	625	618	292	461	377	897
April	234	446	172	20	133	224	110
May	149	346	-83	-182	-142	91	-905
June	-57	78	-343	-198	-437	-144	-1453
July	72	50	58	115	-150	-97	-492
August	-40	0	30	40	-231	-131	-642
September	-68	22	18	4	-6	-74	-282
October	16	40	50	125	-66	7	149
November	210	191	167	105	308	180	749
December	522	641	582	465	679	439	1798
TOTAL	2831	4252	2952	1499	1776	1967	3226

E1 = Morganza Floodway
E2 = Alabama Bayou
E3 = Bayou des Glaises
E4 = Pigeon Bay
E5 = Flat Lake
E6 = The Crevasse
E7 = Upper Belle River

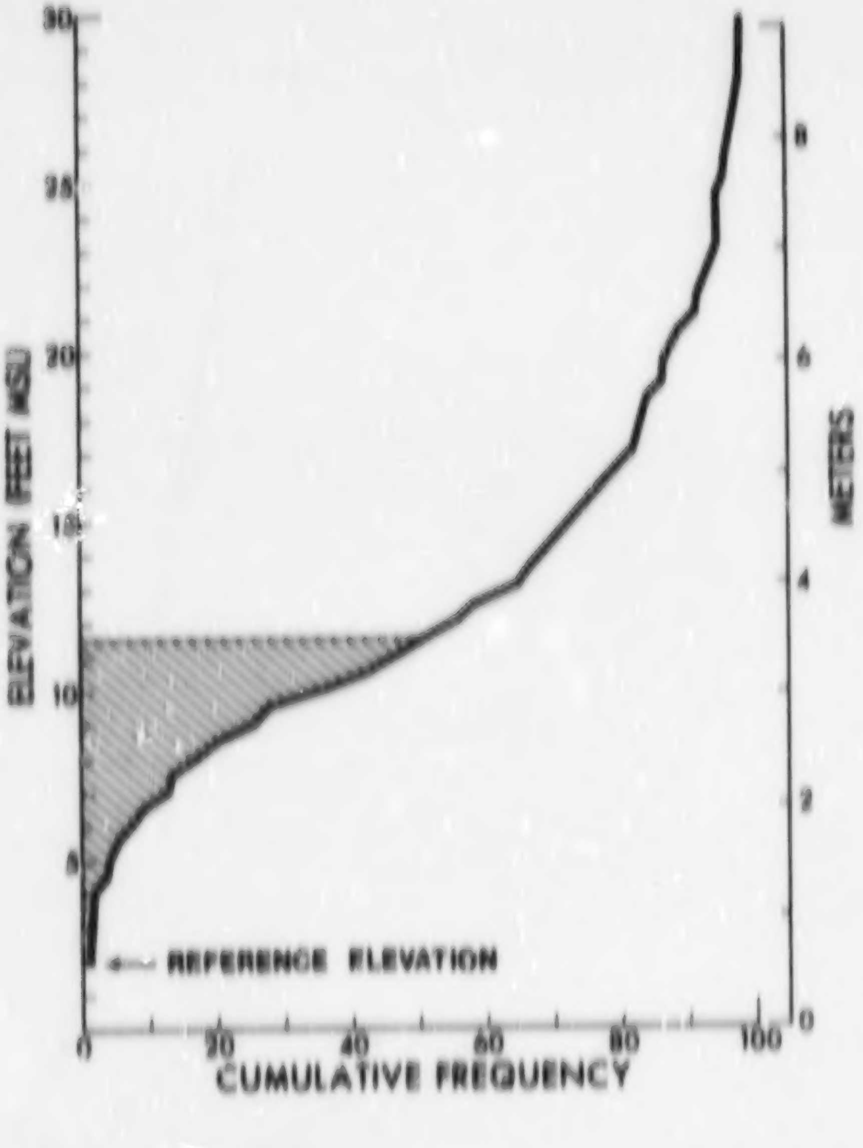

Figure 7-20. Graph showing use of hypsometric curve in determining storage capacity of management unit for given water level. Shaded area is representative of storage content.

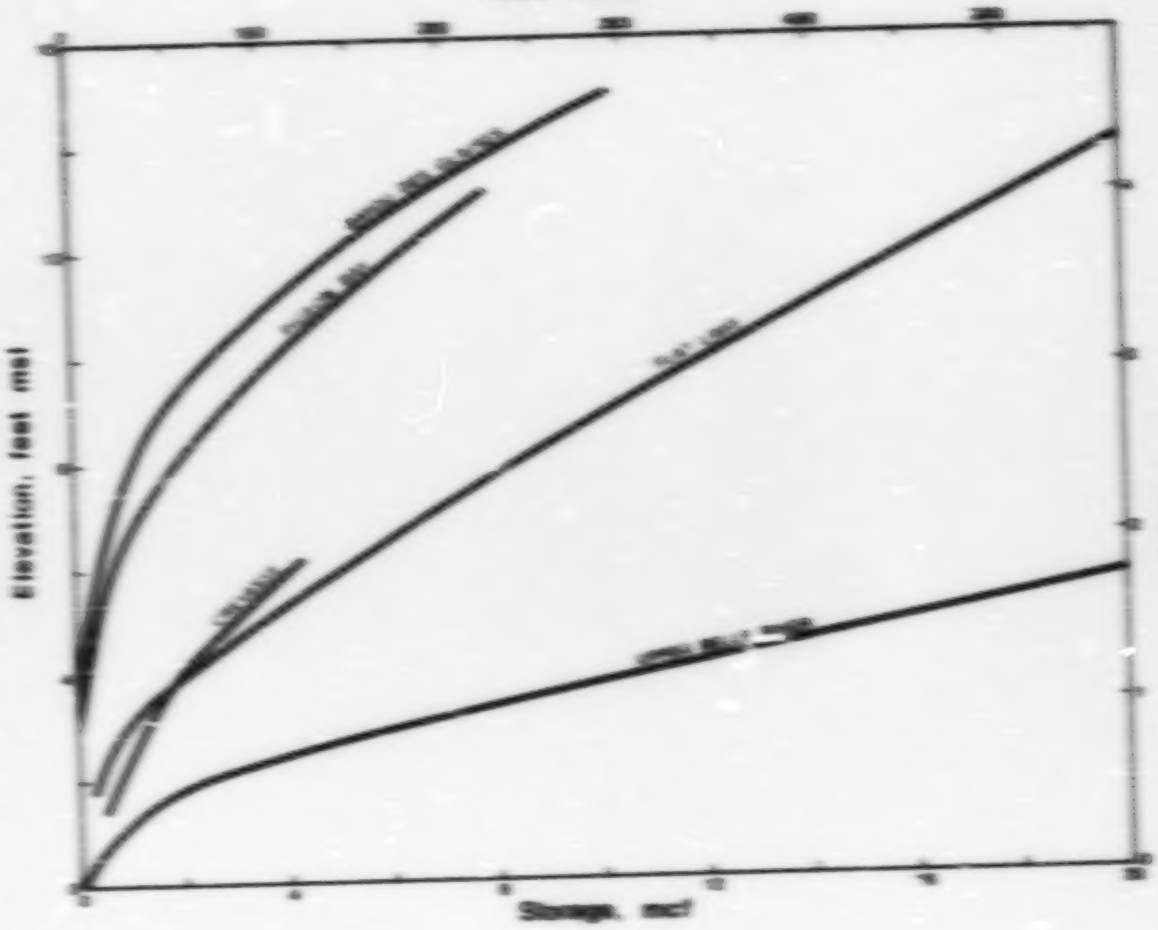

Figure 7-21. Storage elevation curves for management units in east floodway. Curves relate stored volume of water to stage.

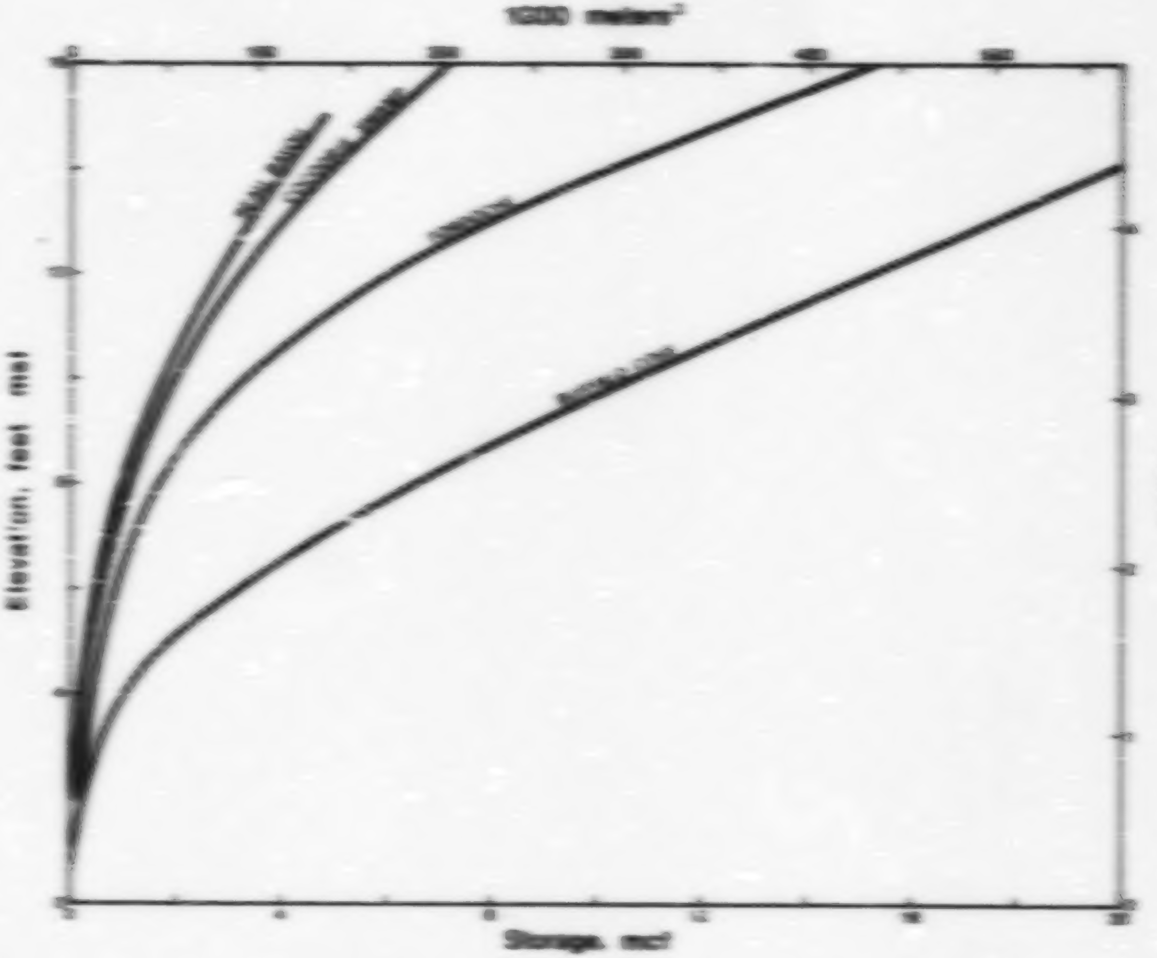

Figure 7-22. Storage elevation curves for management units in west floodway. Curves relate stored volume of water to stage.

VIII
THE PRESENT AND FUTURE MAIN CHANNEL

Throughout this study, the assumption has been made that overriding use for the middle basin is as a floodway, with the Main Channel the principal element in flood control. To meet flood control requirements, the channel should maximize sediment movement through the basin so that reduction of floodway cross-sectional area, and deterioration of aquatic habitat as well, is kept at a minimum. This requires minimization of deposition in the overbank area and of channel in-fillings requiring maintenance dredging and spoil deposition.

Minimization of overbank deposition requires control over diversion of sediment-laden water into the backwater areas. Minimizing channel maintenance requires that the proposed Center Channel conform as closely as possible to a stable, natural channel whose dimensions are in equilibrium with the Atchafalaya River regime of discharge and sediment load. From the point of view of energy expenditure, it is furthermore desirable to capitalize on the useful energy provided by the river in obtaining channel modification required for flood control.

The above aspects will be considered here in the light of present channel conditions and trends at locations referenced in Figure 8-1, and relationships between channel geometry and flow parameters. Results will then be compared with hydraulic geometry and related aspects of the proposed Center Channel.

Channel Dimensions

Present and proposed channel dimensions are summarized in graphical form in Figures 8-2 and 8-3. Figure 8-2 shows the channel cross-sectional area for bankfull stage at subsequent intervals of 4 km (2.5 miles) below the origin of the Atchafalaya River. Channel areas used for 1963 and 1970-73 (most recent) are those presented for bankfull condition in the U.S.C.E. Environmental Statement Appendix.[159] Bankfull area for the proposed Center Channel was calculated from cross sections provided by the U.S.C.E., New Orleans District. Most recent and 1963 cross-sectional data reveal a relatively stable channel over the first 50 miles, with an average value of 8980 m^2 (96,000 ft^2). It should be pointed out that this value concerns the channel proper. As explained previously, channel cross section is larger when taking into account the artificial levees extending the channel banks upward. In the latter case, the channel exceeds 9300 m^2 (100,000 ft^2). Between mile 50 and 55, cross section rapidly decreases. The most recent survey shows a

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[159] U.S. Army Corps of Engineers, 1974, _op.cit._

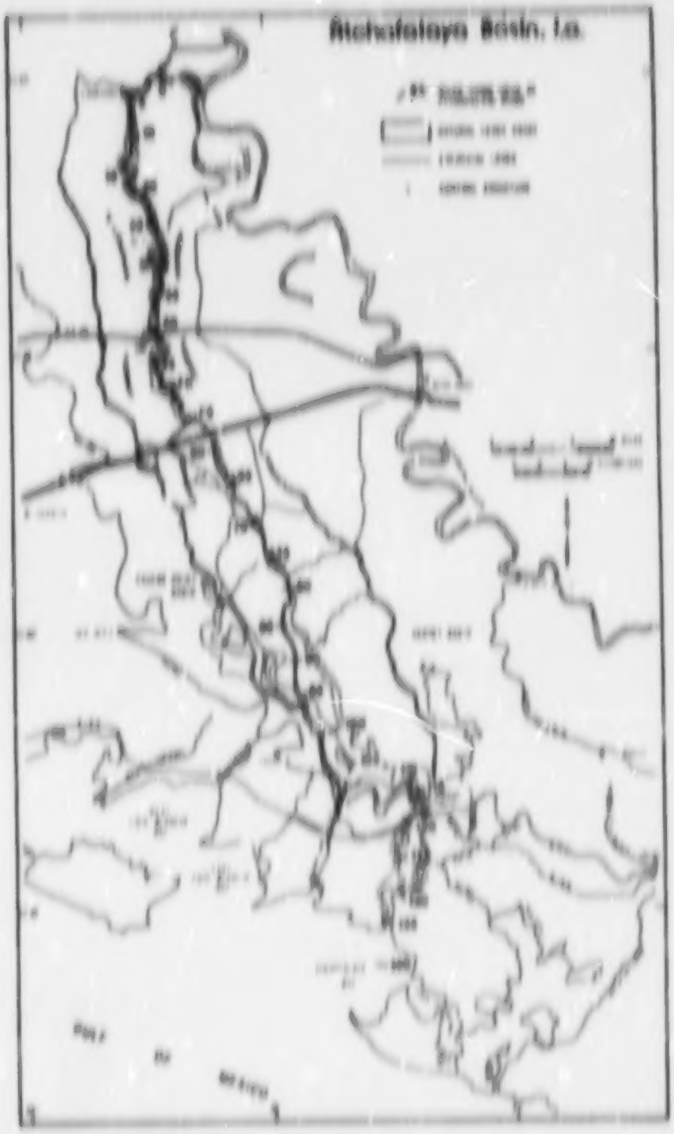
Atchafalaya Basin, La.

Figure B-1. Reference location along Main Channel of Atchafalaya River.

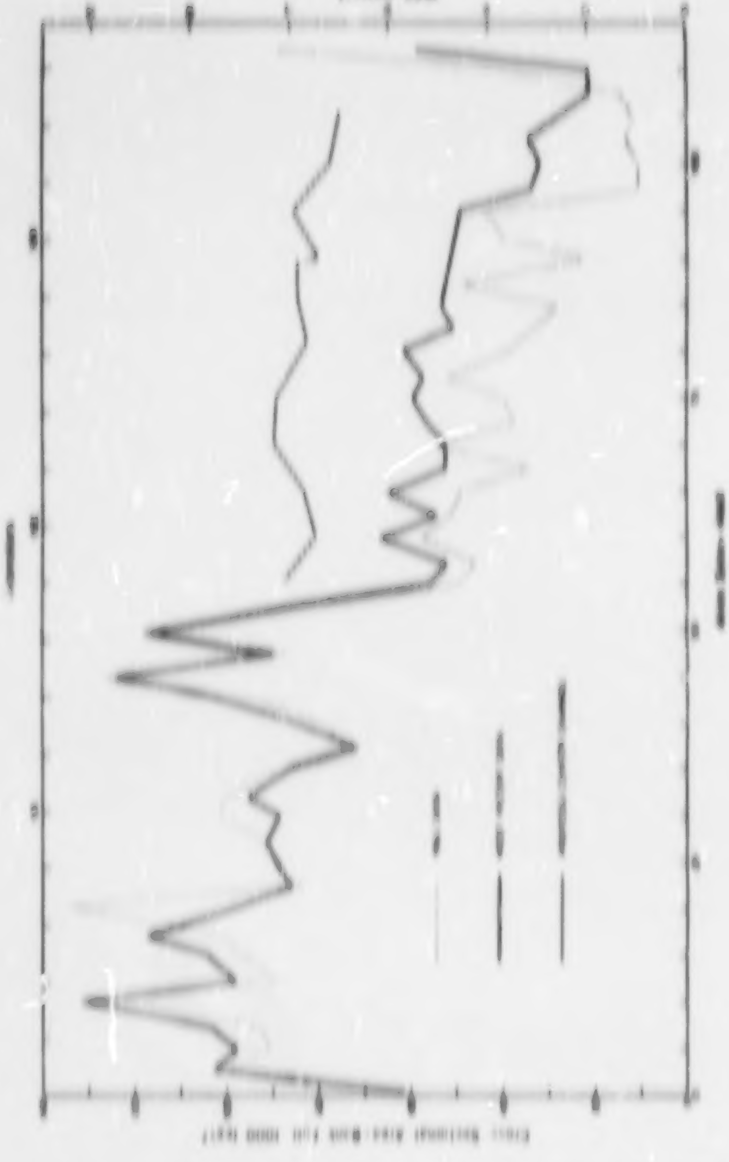

Figure 8-2. Cross-sectional area of Main Channel below bankfull level as defined by topography. Dimensions are shown for 1963, most recent (1969-72), and proposed Center Channel conditions.[160]

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[160] U.S. Army Corps of Engineers, 1974, *op. cit.*

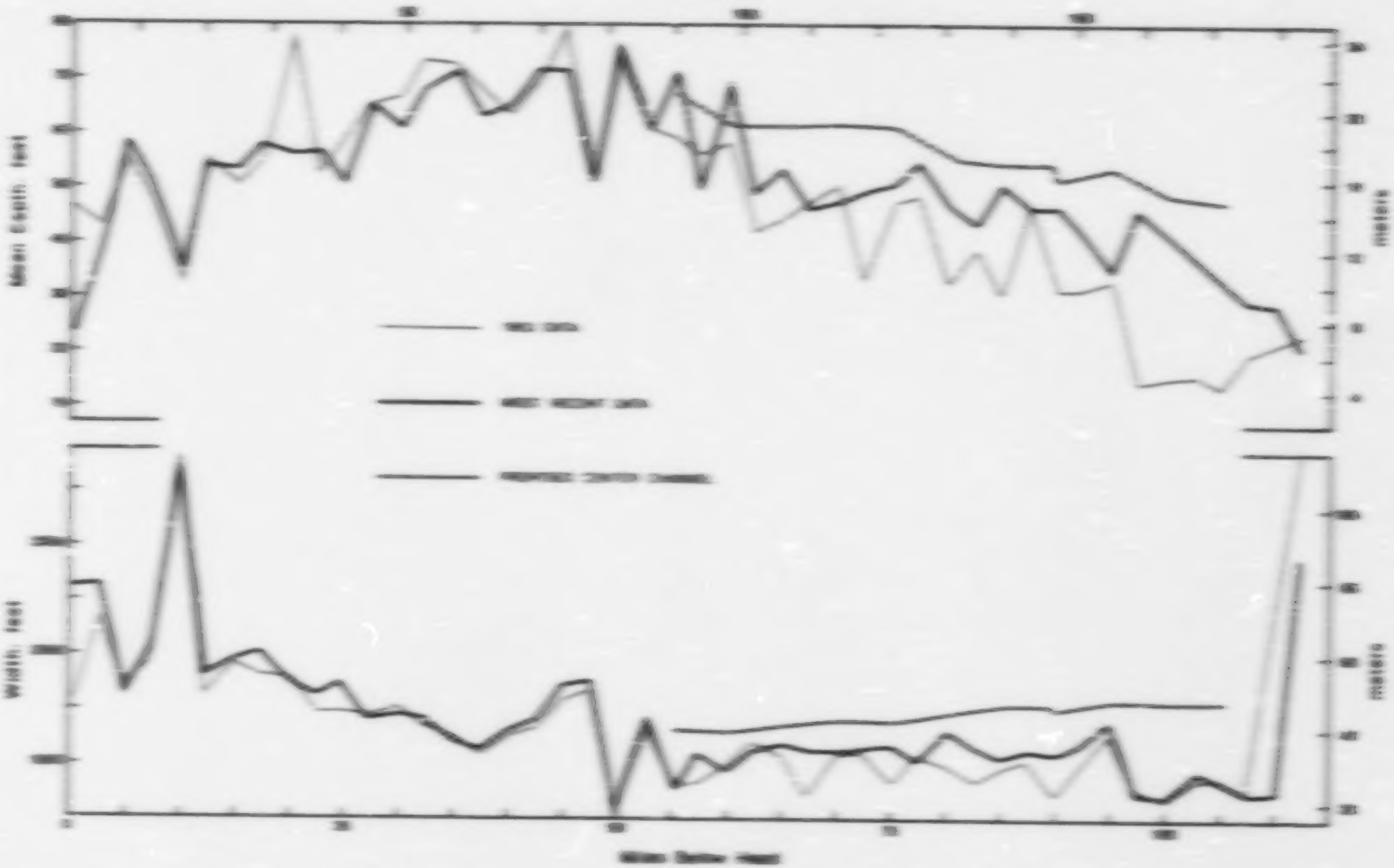

Figure 5-1. Width and mean depth of Main Channel at bankfull stage for 1963, most recent (1969-1977), and proposed Center Channel conditions.

cross section of approximately 5100 m^2 (55,000 ft^2) between mile 50 and 80 and a further decrease to 4650 m^2 (50,000 ft^2) at mile 95, and 1850 m^2 (20,000 ft^2) at mile 110.

A number of factors contribute to the various decreases in cross sections downstream from mile 50. One is youth of the channel. Geologically speaking, conversion from a series of lakes to a generally confined channel has only occurred recently or is still ongoing, such as in Six Mile Lake, from mile 100 to 110. A second major factor relates to loss of channel discharge in the downstream directions. Whereas even the highest discharges are contained by the channel above mile 55 because of continuous artificial levees, below mile 55, increasing volumes of water are diverted from the Main Channel as discharge increases. For a flow slightly above bankfull discharge, 30 percent of the flow is diverted at mile 50 from the Main Channel into the old Atchafalaya River channel, with only 11 percent returning at the downstream confluence. Further loss amounting to about 15 percent occurs at the East Freshwater Diversion and Access Channels and through lesser openings in the banks. In other words, between mile 55 and mile 95, the Main Channel is only carrying from 60 to 70 percent of the original discharge since most water is diverted into the overbank area to the west. A temporary increase in discharge occurs between mile 95 and 100 as water from the western swamps is routed back into the channel. However, 30 percent of the original discharge is again diverted from the Main Channel at mile 100 toward Wax Lake Outlet. Thus, for most of the distance between mile 100 and 110, only about 50 percent of the original discharge is contained by the Main Channel. Prior to entering the Lower Atchafalaya River, flow is increased again to 70 percent through drainage from the eastern swamp basin. Comparison of the above information with Figure B-2 immediately shows that successive decreases in cross-sectional area reflect the identified decreases in discharge.

Since 1963, cross-sectional area has increased by approximately 30 percent in the lower channel below mile 55, as illustrated by the diagram (Figure B-2). The increase resulted partially from dredging and spoil deposition that limited overbank escape of channel flow. Since the proportional contribution of natural and human processes is not fully known to the authors, no accurate estimate can be made here of the natural rate of increase. Natural enlargement to the proposed dimension shown in Figure B-2 has been estimated at a period of 40 years under present conditions of flow distribution;[161] through dredging, enlargement is estimated to take a period of 15 years.

The proposed channel cross section is seen to represent basically a continuation of the cross-sectional trend established along the river above mile 55. Since no changes are planned to eliminate major routes of flow diversion from the lower channel, the question arises as to what extent the proposed cross section will be in adjustment to the normal Atchafalaya River regime and whether the proposed channel will be self-maintaining. The following discussion will address these questions.

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[161] *Ibid.*

Hydraulic Geometry

No channel will be stable throughout the range of discharges experienced by the Atchafalaya River. Scour and infilling will alternate with annual changes in discharge. However, it is generally accepted that the geometry of mature stream channels is governed by flow characteristics for bankfull discharge, which is defined as that discharge having a recurrence interval of 1.58 years.[162,163] Analysis of Atchafalaya River flows revealed that bankfull discharge as based on frequency of occurrence can be set at 11,330 cms (400,000 cfs). For this discharge, hydraulic geometry and associated parametric values can be obtained for the Main Channel in its stable upper reaches. Through processing of weekly data obtained by the U. S. Corps of Engineers at Simmesport (mile 4.8),[164] rating curves and equations were developed relating discharge (Q) to stream width (W), mean depths (D), cross-sectional area (A), mean velocity (V), and stage (H). Figures B-4 and B-5 show the curves; the following relationships were obtained:

M.S	E.S	
$D = 1.571Q^{0.2297}$	$D = 2.273Q^{0.2297}$	(1)
$W = 117.6Q^{0.1433}$	$W = 231.5Q^{0.1433}$	(2)
$A = 184.8Q^{0.3730}$	$A = 526.3Q^{0.3730}$	(3)
$V = 0.0054Q^{0.6270}$	$V = 0.0019Q^{0.6270}$	(4)

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[162] L. B. Leopold, et. al., Fluvial Processes in Geomorphology (San Francisco: W. H. Freeman and Company, 1964), 522p.

[163] G. Dury, " Magnitude Frequency Analysis and Channel Morphology" (State University of New York, Binghamton, New York, in M. Morisawa, ed., Fluvial Geomorphology, Publications in Geomorphology, 1973), Part 2.

[164] U.S. Army Corps of Engineers, Stages and Discharges of the Mississippi River and Tributaries and Other Watersheds in the New Orleans District for 1965 (New Orleans District, New Orleans, Louisiana, 1965), 403 p.

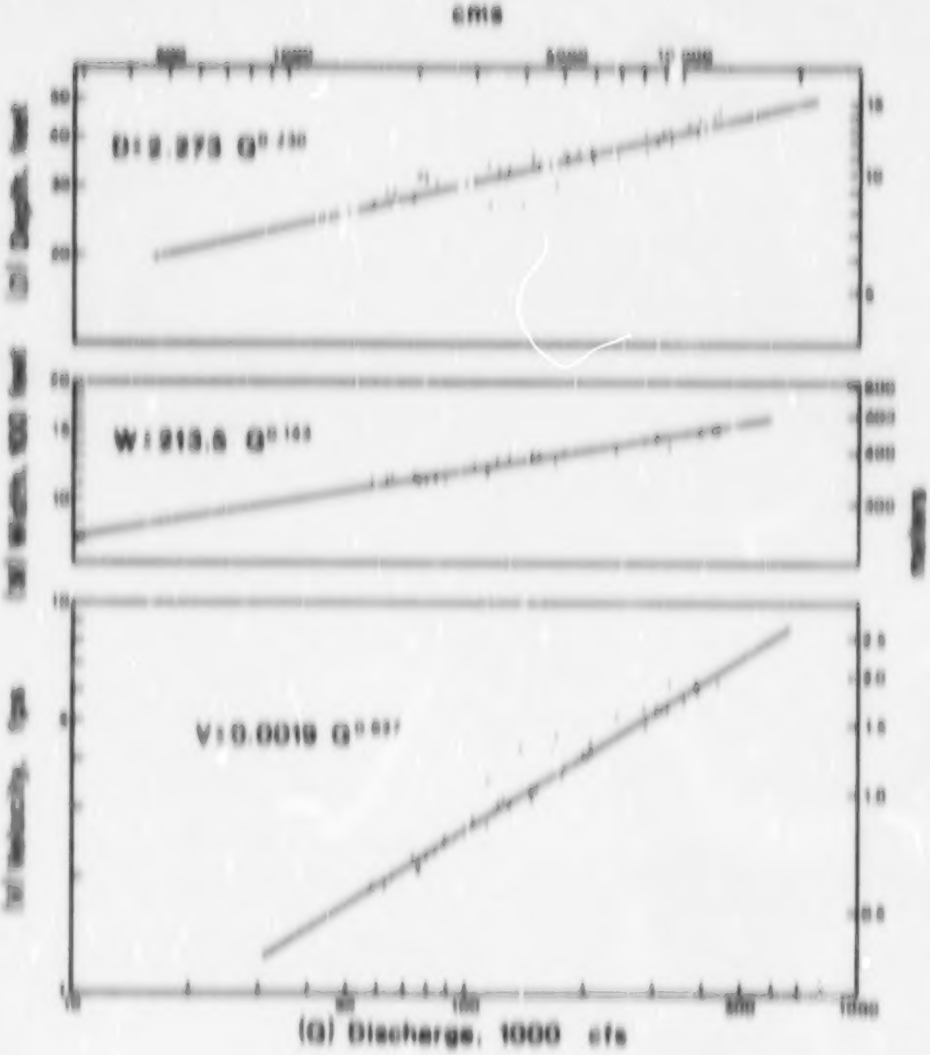

Figure 8-4. Relationships between mean depth, width, mean velocity, and discharge of Atchafalaya River at Simmesport, Mile 4.8.[165]

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[165] *Ibid.*

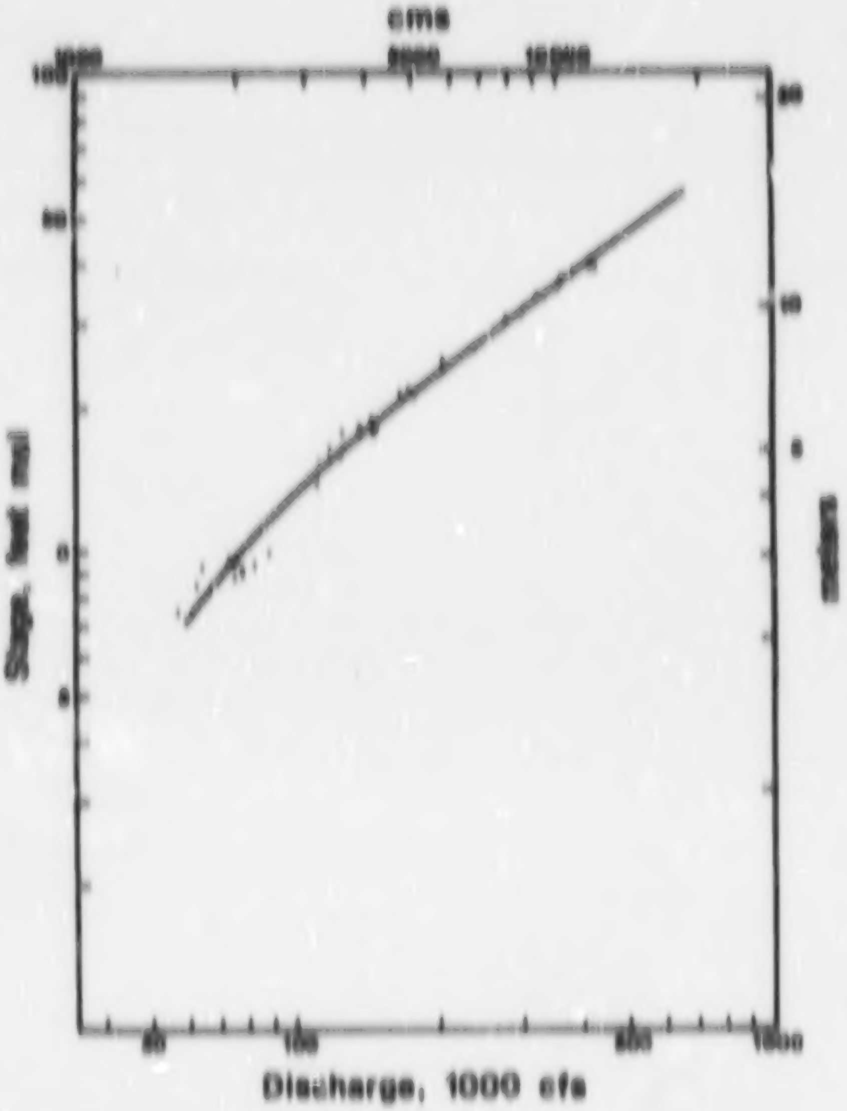

Figure 8-5. Stage-discharge relationship for Atchafalaya River at Simmesport, mile 4.8.[166]

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[166] Ibid.

Table 8-1 summarizes flow conditions for 11,300 cms (400,000 cfs) discharge also including the gradient (S) and Manning's roughness factor (n).

Table 8-1. Flow Parameters, Atchafalaya River, Mile 4.8.

Q		D		W		A		V		B(MSL)		S	n
cms	cfs	m	ft	m	ft	m^2	ft^2	m/s	ft/s	m	ft	.000059	.023
11,300	400,000	13	44	448	147	6009	64685	1.9	6.2	11.9	39		

With the obtained relationships, theoretical channel dimensions can be determined if a trapezoidal, cross-sectional shape and a bank slope of 0.3 in accordance with the natural channel are assumed. The channel cross section as obtained for 11,300 cms (400,000 cfs) is shown in Figure 8-6 together with the actual cross section.

Comparison of the two cross sections shows fair agreement in terms of shape and width, but depth is considerably greater in the actual channel. This difference appears most important. The actual profile was surveyed during low discharge and stage. When calculating channel shape for such a low discharge, it is found that bottom elevation decreases. For instance, for a discharge of 2000 cms (70,000 cfs), bottom elevation for the theoretical channel is found to be 7 m (23.2 ft) below mean sea level, or 4 m (13 ft) lower than the bottom elevation obtained for the 11,300 cms (400,000 cfs) discharge. In other words, the obtained relationships indicate that during increasing discharge,bottom elevation is raised. Yet cross-sectional area increases because of a more rapid rise in water level and a trapezoidal channel shape. This is illustrated in Figure 8-7 on the basis of the obtained relationships. The same process has been observed to occur under natural conditions[167] and might relate to the rate of increase of suspended sediment concentration with increasing discharge.[168]

Prior to examining the consequences of the above analysis, one additional observation should be made. The presence of artificial

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[167] Leopold _et. al._, 1964, _op. cit._

[168] L. B. Leopold and T. Maddock, Jr., _The Hydraulic Geometry of Stream Channels and Some Physiographic Implications_ (Professional Paper 252, U. S. Geological Survey, Washington, D. C., 1953), 56 p.

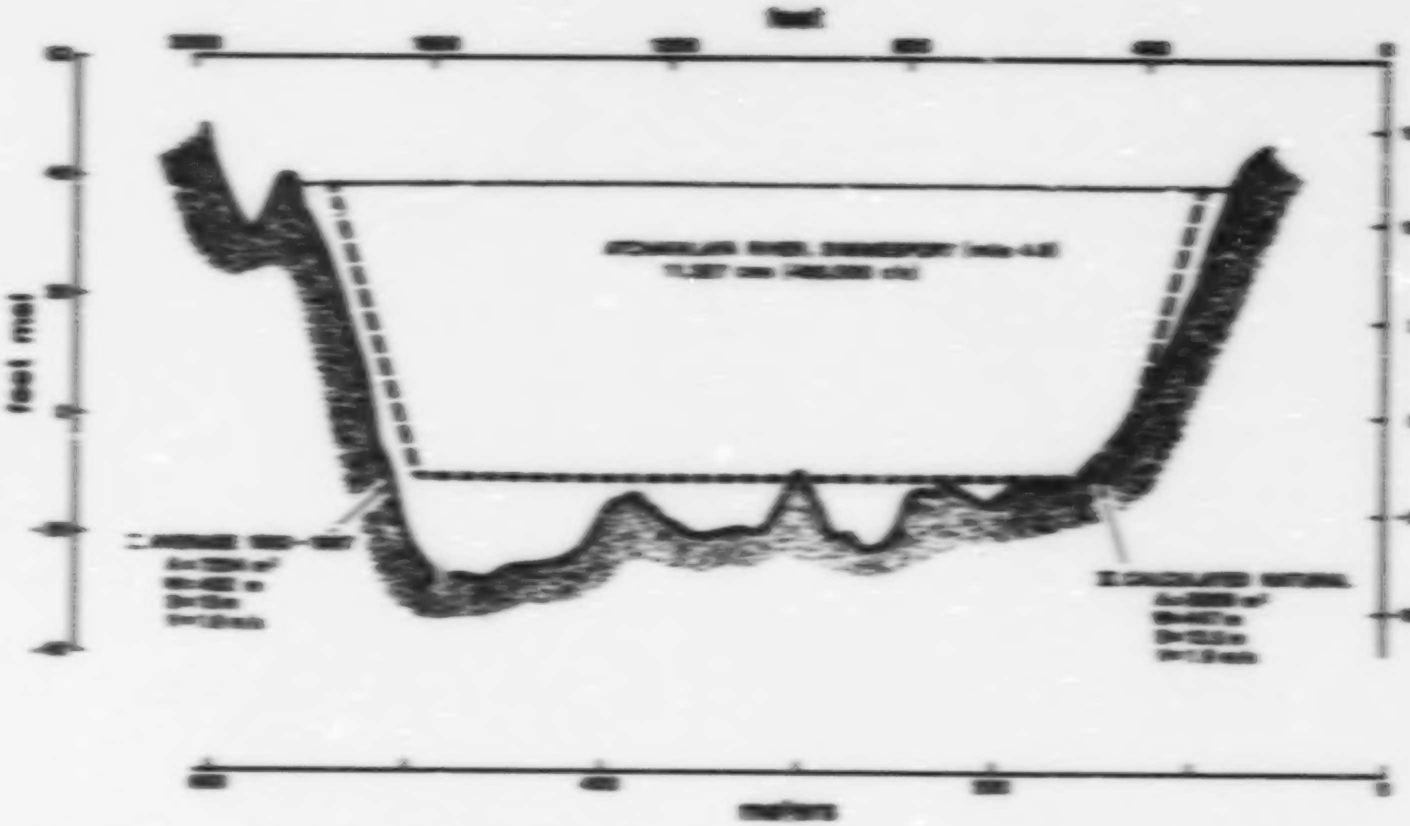

Figure 6-5. Cross sections of Atchafalaya River at Simmesport, mile 4.8, obtained from U.S.C.E. survey and through calculations, respectively.[illegible]

[illegible] U. S. Army Corps of Engineers, 1974, op. cit.

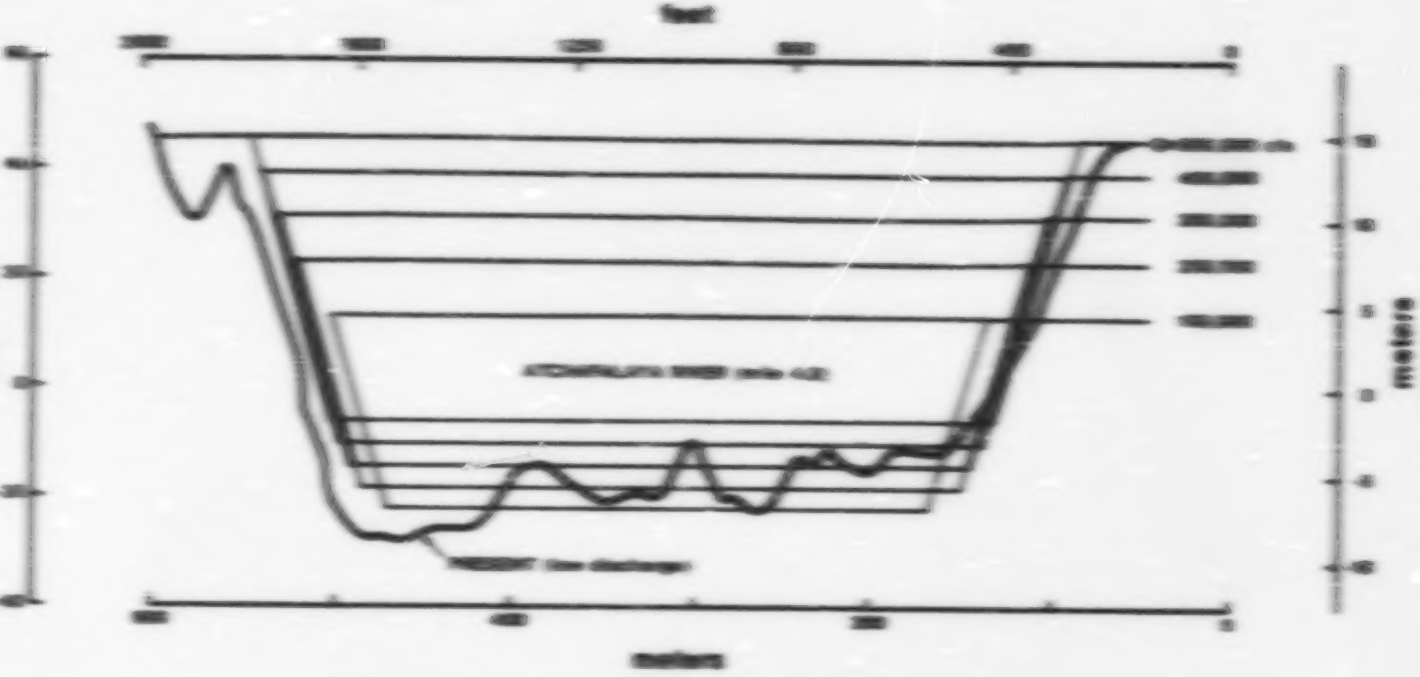

Figure 8-7. Cross sections of Atchafalaya River at Simmesport, mile 4.8, as obtained from calculations for various discharges.

levees along the upper reaches of the Main Channel confines flow also for discharges above 11,300 cms (400,000 cfs). As a result, stages for a given discharge exceeding the latter value are higher than they would be under natural circumstances, where the river would overflow into the floodplain; channel banks are therefore allowed to build up to a higher level. The artificial levees have the effect of increasing the magnitude of flow at which bankfull discharge is reached. In the cross section analyzed in Figure 8-6, bankfull discharge as defined by topography is attained at a stage of 14.3 m (46.8 ft) MSL,[170] which is associated with a discharge of about 14,150 cms (500,000 cfs) rather than the 11,300 cms (400,000 cfs) expected if natural conditions prevailed. Channel cross-sectional area for this larger discharge as obtained from Equation (3) is 6,500 m^2 (70,300 ft^2).

The above value is considerably smaller than those indicated in Figure 8-2. Only by taking the total area containing all probable channels for discharges below 14,000 cms (500,000 cfs) is a cross-sectional value of about 8400 m^2 (90,000 ft^2) obtained. Consequently, to place cross-sectional data in a proper perspective, it should be stated that 1) self-maintaining channel capacity for bankfull discharge is about 6000 m^2 (65,000 ft^2), and 2) in the presence of artificial levees, the area utilized by the Atchafalaya River for discharges up to 14,000 cms (500,000 cfs) is in the order of 8400 m^2 (90,000 ft^2).

Probable Natural Channel

One may now view the overall Atchafalaya River system in order to obtain a notion of the dynamic equilibrium conditions the river is attempting to realize. For this purpose, a single channel is assumed connecting the Mississippi River and Atchafalaya Bay, having a bankfull discharge of 11,300 cms (400,000 cfs) and a length of 225 km (140 miles). Furthermore, it is assumed that conditions at the head of the river are stable at present. Thus, limiting conditions for the following discussion are length (L) = 225 km (140 miles) for a discharge of 11,400 cms (400,000 cfs), stage at mile 4.8 ($H_{4.8}$) = 11.9 m (39 ft), stage at mile 140 (H_{140}) = 0m (0ft) and slope at mile 4.8 ($S_{4.8}$) = 0.000059 km/km.

First, the probable flowline can be determined. Applying the concept that in an open system the distribution of energy tends toward the statistically most probable, it follows that the most probable stream profile for a poised river is exponential in form.[171,172,173] The most probable river profile can thus be defined as

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[170] U. S. Army Corps of Engineers, 1974, op.cit.

$$X = ae^{-bH} + c \qquad (5)$$

or

$$H = -\frac{1}{b} \ln \left(\frac{a}{X - c}\right), \qquad (6)$$

where X is the distance along the stream as measured from the head of the river (X_0), H is the elevation above base level at a point along the stream, and a, b and c are constants. From equation 5, river slope (S) can be obtained as

$$S = \frac{dH}{dx} = -\frac{1}{b} \left(\frac{1}{x - c}\right). \qquad (7)$$

For the limiting conditions stated earlier ($H_{4.8}$ = 11.9 m (39 ft); H_{140} = 0 m (0); $S_{4.8}$ = -.059m/km (-0.31152 ft/mi)) (6) and (7) can be solved for a, b, and c, so that the river profile becomes

$$H_x = 256.65 \ln \left(\frac{959}{x + 819}\right) \text{ (ft)} \qquad (8)$$

and slope

$$S_x = \frac{dH}{dx} = -256.64 \left(\frac{1}{x + 819}\right) \text{ (ft/mi)}. \qquad (9)$$

In Figure 8-6, the obtained stream profile is shown together with present and proposed profiles for 11,300 cms (400,000 cfs) as obtained

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[171] L. B. Leopold and W. B. Langbein, The Concept of Entropy in Landscape Evolution (Washington D. C.: Professional Paper 500-A, U. S. Geological Survey, 1962), 20 p.

[172] J. T. Hack, "Drainage Adjustments in the Appalachians" in Fluvial Geomorphology, ed. M. Morisawa (Binghamton, New York: Publications in Geomorphology, 1973), Part 1.

[173] J. T. Hack, Studies of Longitudinal Stream Profiles in Virginia and Maryland (Washington, D. C.: Professional Paper 294-B, U. S. Geological Survey, 1957).

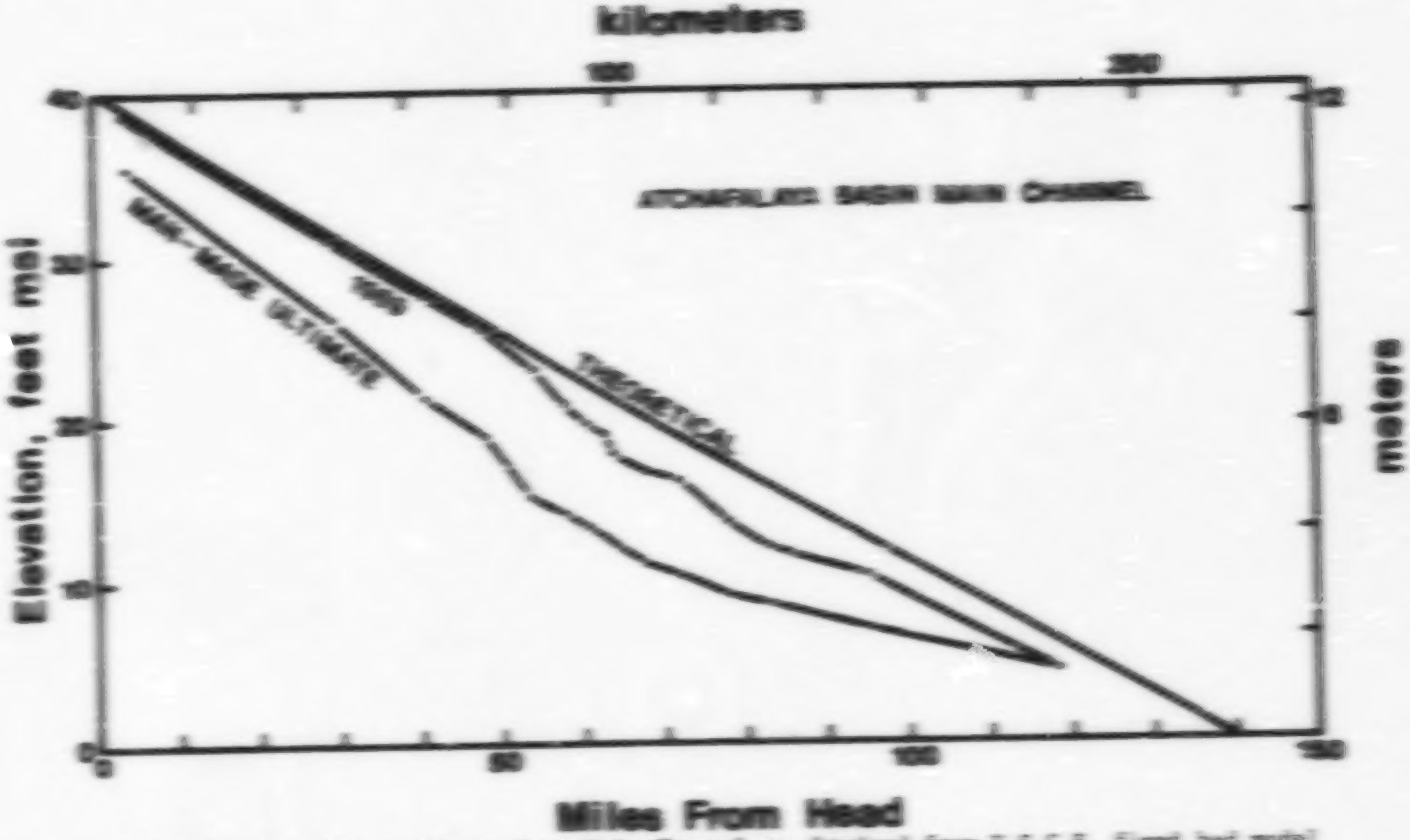

Figure 9-6. Water-surface profiles along Main Channel as obtained from U.S.C.E. fixed bed model study for present (1969) and proposed Center Channel (manmade ultimate) conditions, and for most probable equilibrium condition (theoretical). Assumed discharge is 11,300 cms (400,000 cfs).[174]

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[174] U.S. Army Corps of Engineers, 1974, pp. 122-

from the U.S.C.E. model report.[175] Comparison of the profiles shows coincidence of present and probable equilibrium conditions in the upper half of the stream, supporting the assumption of a stable channel in that reach. Center Channel conditions can be observed to move the river in a direction away from dynamic equilibrium by further decreasing an already low gradient in the lower reaches. On the basis of deviation between present and theoretical profile, a trend toward increased gradient and stage must be expected for the lower channel. This can be partly substantiated by Figure 8-9, which shows such a trend at both Morgan City and Wax Lake Outlet over the past 30 years. At Morgan City, the average increase has been 0.017 m (0.055 ft) annually. Projection of this rate suggests that natural channel development would take approximately 45 years.

To further evaluate proposed and present conditions, one can compare channel cross sections with their respective probable future cross sections. Figure 8-10 shows the cross section at mile 75, approximately halfway down the proposed Center Channel. Water levels shown are those associated with an 11,300 cms (400,000 cfs) discharge, as obtained from the U.S.C.E. model study[176] and equation (8). Cross section for the probable equilibrium condition was calculated using the procedure outlined for mile 4.8, but taking into consideration the lesser gradient as obtained from equation (9). Mean velocity was assumed constant over the entire channel length in accordance with natural streams.[177] In the absence of tributaries, discharge must also be assumed to be constant and, consequently, cross-sectional area. Roughness was assumed constant on the basis of constant velocity and sediment load.

Comparison of the profiles suggests 1) that the channel trend should be toward a larger width, and 2) that width of the proposed channel is excessive and is not in equilibrium with the Atchafalaya River discharge and load regime. The first suggestion is supported circumstantially by the fact that an increase in width from 256 m (840 ft) to 357 m (1170 ft) over the period 1951-1969 has been maintained.

The second conclusion can be supported by the following consideration. The cross-sectional area occupied by flow in the proposed channel measures 7150 m^2 (77,000 ft^2). For a discharge of 11,300 cms (400,000 cfs), a velocity of 1.58 m/sec (5.2 ft/s) would be required. Design gradient, however, is only 0.000025 while hydraulic radius measured 13.9 m (45.5 ft). For an assumed roughness of 0.023, the

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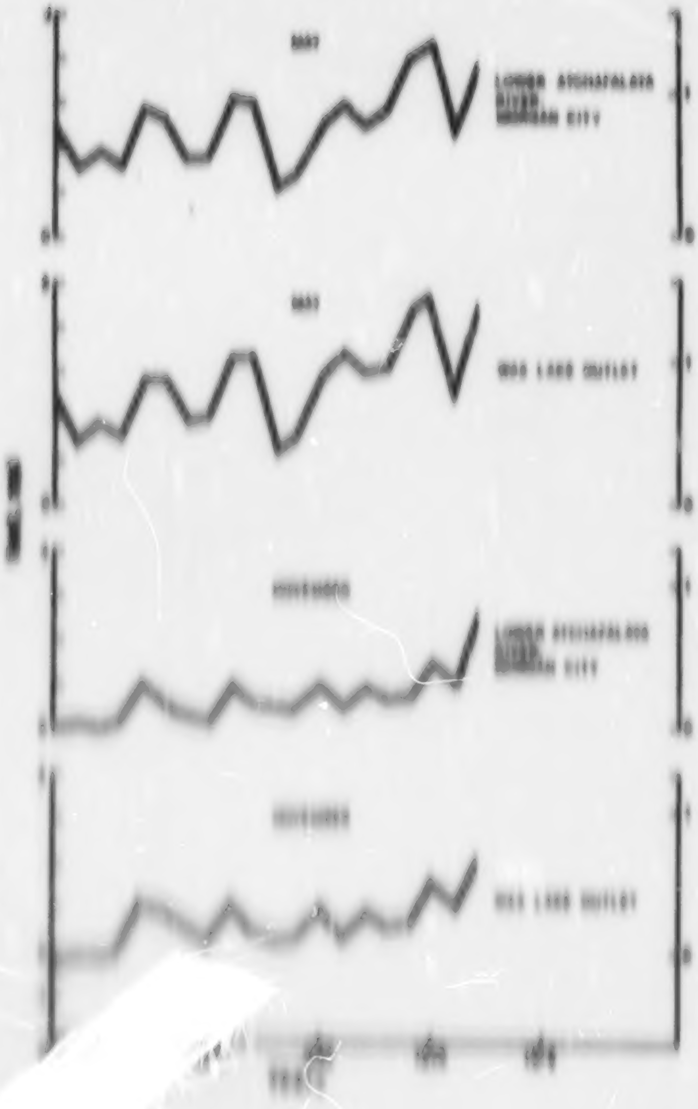
[175] U. S. Army Corps of Engineers, 1974, op. cit.

[176] Ibid.

[177] Leopold et al., 1964, op. cit.



[illegible] of river stage for Lower Atchafalaya River at Morgan City and Wax Lake Outlet at Calumet for [illegible] Mean monthly stage for high and low discharge months, respectively.

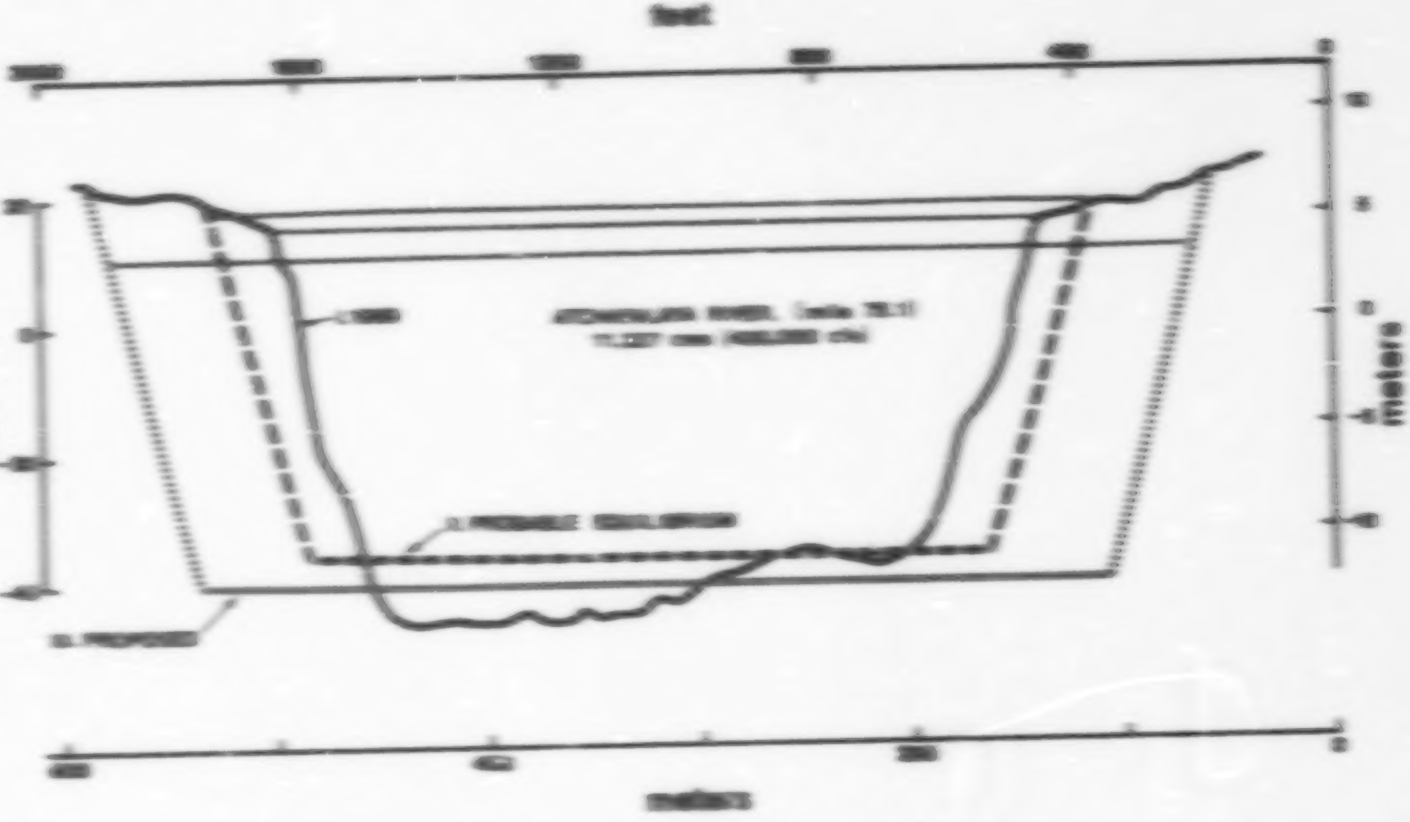


Figure 5-20. Cross sections of Atchafalaya River Main Channel at mile 75.1 as surveyed in 1969, as proposed, and as obtained for most probable equilibrium conditions at bankfull discharge.

Manning equation yields a velocity of 1.2 m/sec (4.0 ft/s). Under this condition, the stream can be expected to respond by reducing its width, maintaining cross-sectional area through a corresponding rise in water level which, in turn, produces an increased hydraulic radius and slope and, consequently, an increase in velocity. Width reduction can only be obtained through sediment deposition. Both the reduction in width and the rise in water level are seen to move in the direction of equilibrium channel conditions.

Two additional points should be made. First, it should be noted that the required 1.58 m/sec (5.2 ft/sec) represents a considerable decrease in velocity from the 1.9 m/sec (6.1 ft/sec) associated with the same discharge in the upper channel section. Consequently, carrying capacity of sediment load must be expected to decrease and to result in additional sedimentation. Secondly, flow diversion, which ranges from 20 to 30 percent of the discharge, has been ignored. This, in effect, decreases the channel controlling discharge and, consequently, the self-maintaining channel cross section.

In summary, analysis of hydraulic geometry under the present Atchafalaya River regime of discharge and sediment load suggests that the proposed Center Channel dimensions, particularly width, exceed those required by the channel controlling discharge of 11,300 cms (400,000 cfs). On the basis of the previous analysis, it is believed that an efficient, self-maintaining channel cannot be realized if cross-sectional area below the projected floodflow line exceeds 7,500 m^2 (80,000 ft^2) and a width of about 425 m (1400 ft). Exceeding this magnitude by 1850 m^2 (20,000 ft^2), or 25 percent, in order to obtain a dynamic equilibrium and optimum flow efficiency for project flood discharge conditions appears to ignore the fact that the Center Channel will adjust to its resident stream rather than to a low frequency occurence, such as major floods requiring maximum diversion of Mississippi River discharges.

IX
PLAN FOR MANAGEMENT OF THE ATCHAFALAYA BASIN

In this chapter, we shall first define zones and strategies for land and water management which will best accommodate, in our view, the many management possibilities that are presently or potentially important in the Atchafalaya Basin. Secondly, a detailed surface water management plan will be set forth.

Definition of Management Zones

The management zones are meant to incorporate as many possible existing land uses that are compatible with the major management objectives. In the Atchafalaya Floodway, for instance, the primary management objective must be flood control since this is of key importance to a large segment of Louisiana. However, the acceptance of this as a primary use does not preclude needs to mitigate as much as possible the effects of flood control on other uses. Certainly this should be done in cases where the mitigation actually might enhance flood-control use. As we shall show in the following, there are many opportunities for compatible multiple use of this kind.

Management zones are grouped into three categories,which we term zones of protective use, exploitative use, and a buffer zone (Figure II-1). The zone of protective use includes mostly the present areas of swamp forest and other bottomland forests that have been least utilized by humans other than for flood-control purposes. The zone of exploitative use includes those areas where substantial human development has already occurred mostly from agricultural, urban, industrial, and residential uses. The buffer zone is proposed herein as a tract lying between the two in which planning should focus on ways to minimize the many conflicts between exploitative and protective use.

It should be realized, however, that in actual fact these divisions are somewhat arbitrary. All of these zones are presently under exploitative use by humans. The Atchafalaya Floodway is certainly in exploitative use since it is a floodway. By including it in the zone of protective use as we do, we mean to emphasize that our principal concern should be protection not only of wildlife and vegetational habitat value, but also of its value for human use as a floodway.

On the other hand, lands in exploitative use,such as the agricultural lands,also deserve much consideration in order to protect their quality as agricultural lands. So protective-use considerations are extremely important in this case as well. Also, places within the zone of exploitative use that still retain some more or less natural attributes might also be consigned to protective use

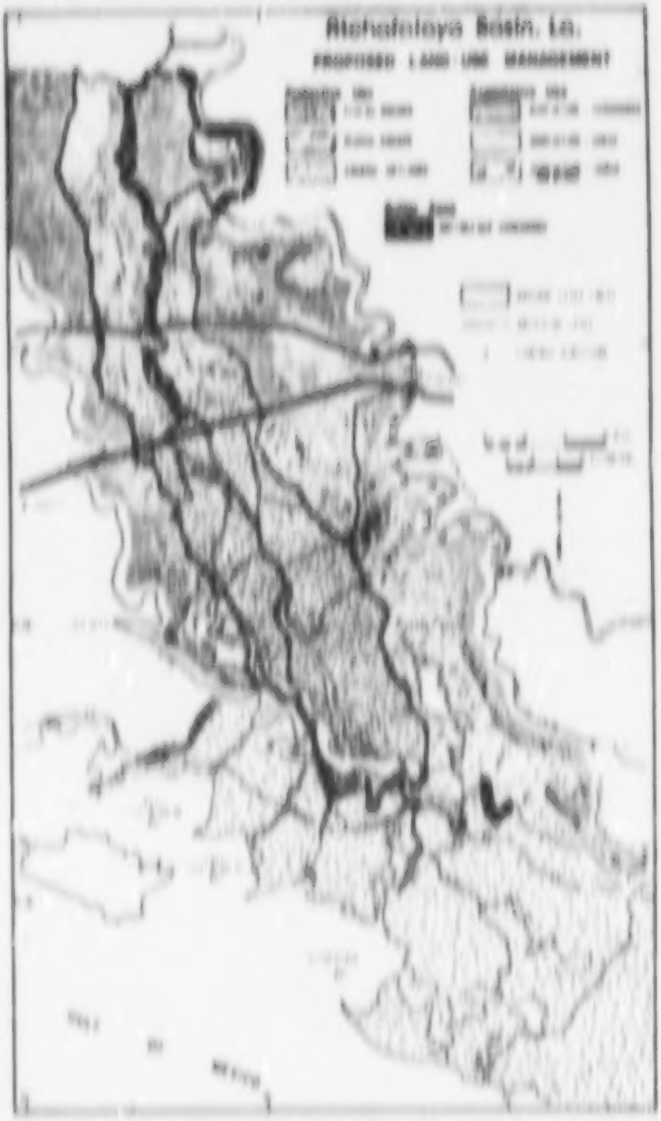

Atchafalaya Basin, La.
PROPOSED LAND USE MANAGEMENT

Figure 9-1. Proposed zonation of protective and exploitative land uses separated by a buffer zone and allowing multi-use management of the Atchafalaya Basin.

management. This would apply to scattered locations where bottomland hardwoods have not been entirely removed.

In the buffer zone especially there will be much mixture of protective and exploitative use. An exploitative use for which this zone might serve would be as a biological tertiary treatment area for municipal wastewater, designed so that it might yield a useful product such as pulpwood, methane gas, methanol, or other chemicals. This use could be considered protective, however, since it could free an even larger area from the impact of pollution. Various schemes of biological water treatment may be used in this buffer zone to process agricultural runoff for recovery of soil and nutrients lost from fields.

We do not propose that the zones outlined on Figure 9-1 be viewed as final or fixed. Rather, the plan should be viewed as flexible, with modification and shifting of zones as it becomes appropriate to do so. Should future trends be toward reduced need of lands in crops or pasture, then the lowest-lying agricultural lands on the flanks of the natural levee ridges could be transferred into the buffer-zone management area, with corresponding transfers from that zone into the zone of protective use. In areas where agricultural lands are presently flood prone, such transfers also might be appropriate in lieu of expanded drainage efforts.

Although the zones as outlined have a banded structure, with exploitative use occurring on the higher ridge lands, buffer-zone use at intermediate levels, and protective-use areas occupying the swamp basins, this should not necessarily be regarded as an ideal or final pattern. It would be highly desirable in the future if needs for land in exploitative use should decline to have zones of protective use extend completely across levee ridges, providing corridors to connect protective-use zones on opposite sides of the levee ridge. These corridors would reduce the present fragmentation and isolation of habitat and increase its diversity.

Strategies for Management

First consideration must be given to flood control of the Atchafalaya Basin since this is of key importance to a large segment of Louisiana and since there are no adequate alternatives to the use of the basin for floodwater routing and storage. Secondary considerations are to bring about as much compatibility as possible of natural resource and cultural use values with the necessary flood-control measures.

Protective Use Zone

Fluvial Swamps

The use of the Atchafalaya Basin with its existing flood control works seems mandatory to any program of flood mitigation in Louisiana's alluvial and coastal lowlands simply because it is the largest available basin in which such a purpose can be accomplished. Additional floodway outlets,such as the Bonnet Carre Spillway and others,which may be required in the future are not likely to significantly reduce the need for this large basin for some time to come.

Relocation of the principal floodway outlet would require large amounts of land now in other use and will create numerous environmental changes of the kind described as occurring in the Atchafalaya Basin. Therefore, it is absolutely imperative that we direct critical attention to means of prolonging for as long as possible the useful life of the basin for flood-control purposes.

A flood-control feature such as the Atchafalaya Floodway serves two useful purposes. It provides storage of floodwaters, and it carries the floodwaters away from areas which might otherwise be endangered. The most effective use, then, of such a floodway should emphasize the following points:

1) The storage capacity or total amount of water which the floodway can hold should be conserved by every means at our disposal. Each time the floodway is used for routing of a major flood,some storage capacity will inevitably be lost through sedimentation. Such losses should be minimized at all other times since the dwindling of storage capacity subtracts irreversibly from the useful life of the floodway. When it is considered that the replacement of this feature would cost an enormous amount, then the value of strict conservation of storage capacity is readily apparent.

2) The ability of the principal channel or channels to carry a large volume of the excess floodwaters should be as great as can be maintained. This increases the amount of water that is carried within the channel and allows for passage of greater total floodwater volume. Just as importantly, however, it also means that a greater proportion of sediment-bearing floodwater will pass through the system without leaving the channel, and therefore will not contribute to sedimentation and loss of storage capacity.

If we are to significantly prolong the useful life of the Atchafalaya Floodway, both of these related points will require critical attention. Although the emphasis given here is to the value of the lands for flood-control purposes, it is readily apparent that the way in which water and sediment are routed through the basin has numerous ramifications related to other uses.

Within the floodway, the management strategy is aimed primarily toward careful and controlled regulation of water inputs. Three of the primary goals of this strategy are to reduce sedimentation, to allow sufficient dewatering, and to protect water quality. Regulated backwater stage-variation will be timed 1) to benefit established tree communities that are intolerant to flooding or sedimentation, 2) to achieve improved tree growth, 3) to benefit crawfishing activity and crawfish reproduction, 4) to benefit fishing activity and fish propagation, 5) to control aquatic weeds, and 6) to improve water quality. Table 7-3 indicated how these objectives are related to lands of five hydroperiod intervals.

It is expected that individual landowners will make the most appropriate uses of lands of varying hydroperiod classes under the managed regimes. Some forms of silviculture may become viable, particularly for tupelo gum, cypress, and green ash, although much of the area may be left to natural forest growth with periodic harvesting. There are, of course, no controls to prevent agricultural development except for the periodic large floods which will probably limit such efforts. Traditional uses, such as fishing, crawfish harvest, trapping, and hunting, should benefit from the proposed management. Wherever possible, wildlife management areas should be established.

Land uses related to flood control presently are centered in the area around the floodway itself, but it is evident that these uses will inevitably come about in the area of delta growth below the Teche Ridge. Places such as Gibson and Amelia, which lie east of Morgan City, already are in need of flood protection from the waters discharged in the delta area.

Pluvial Swamps

The low-lying lands of the Atchafalaya Basin which lie outside of the floodway are referred to here as pluvial swamps since they are largely dependent on local rainfall and runoff derived from drainage systems of adjacent developed lands. One of the greatest conflicts in land and water management in the Atchafalaya Basin is that which exists between such developed areas and those which to some degree retain their natural attributes. In developed areas, which may be of agricultural, urban, suburban, or industrial type, the predominant strategy for water management at present is to remove the water as rapidly as it comes in through rainfall since it is an impediment to many activities related to these kinds of land uses. In order to remove this water rapidly, canals have been dug, streams have been channelized, the terrain has been extensively ditched, and storm sewer systems have been installed. Additional water not derived from local rainfall may also be discharged through municipal, industrial and even residential water supply systems which draw water from the ground or take water from rivers. All such waters discharged from the developed areas may carry with them varying amounts of agricultural, municipal, and industrial pollution.

The undeveloped areas are, for the most part, the lower-lying swamp basins where water removal is too difficult or costly for them to be used in the ways described above. These are used as receiving basins for waters discharged from the developed areas. Thus, these basins are made use of as natural storage areas and treatment systems for such waters. Although it is sometimes said that these uses constitute a "free" work of nature, it is incorrect to think of this as a use without cost since there are usually destructive consequences of use which may be overlooked. For instance, the water which is discharged into the Verret-Palourde Basin from a large area of developed natural levee land along the Mississippi River - Bayou Lafourche - Bayou Black levee ridge contributes to destructive flooding in communities such as Pierre Part, Stephenville, and Gibson. The result of such situations is usually a public demand for more-of-the-same drainage improvements or other systems of flood protection.

The pluvial swamps should be managed for protective use for several reasons. They constitute high quality habitat for wildlife and fish. They have intrinsically high recreational and scenic value. The use of these swamps for runoff routing and storage is essential to present developed areas. One of the most important needs for these lands is due to the fact that, barring completely unanticipated changes in the Mississippi River system, it must be concluded that at some time in the future,the useful life of the present floodway will be ended. For this reason, it is necessary to view the low-lying areas of the basin which lie outside of the present floodway as potential alternate areas for flood diversion. Much of the management strategy that is appropriate for protection of the pluvial swamps does not require action in this zone itself, but requires careful rethinking of the mode of use of the developed lands. Particularly, the amount of runoff water discharged into the pluvial swamp area should be reduced, as should the quantities of associated pollutants. If this is not done, there will no doubt be increased pressure for drainage canals and additional floodwater outlets as well as continued deterioration of water quality in this zone. Means for increasing the storage capacity of water on the lands from which the runoff is derived should be actively investigated. Alternative agricultural techniques which have lesser needs for drainage should be given intensive attention. Human settlements and their accessory developments, such as roads, should be developed by adaptive strategies which lessen drainage needs. Some possibilities of these kinds are discussed in the following sections of this chapter dealing with those lands.

Buffer Zone

It is proposed that a buffer zone be placed between zones managed for protective use and those managed for exploitative use. This zone may be managed in various places either for exploitative or protective uses, but the emphasis should be given to a reduction of certain incompatibilities between the zones to either side. For instance, such a buffer zone situated next to an agricultural area could be used as a biological treatment system for agricultural runoff waters so that when such waters are later discharged into the zone of protective use, they will not contribute pollutants or excessive nutrient loads. Likewise, runoff waters from industrial, municipal, or residential land use areas could be applied after appropriate pre-treatment where necessary.

There are many methods whereby this could be accomplished. The field-drainage systems of the agricultural area could be integrated to deliver waters for various applications in the buffer zone in which productive use might be made of residual nutrients. As a particular example, an area might be managed for short-rotation culture of sycamore for pulp,with use of the agricultural runoff waters for irrigation and fertilization. Periodic harvesting of the trees will allow removal of certain amounts of the accumulated materials that are taken up in the standing crop.

Similar applications by overland flow of polluted waters may be used in more conventional forms of silviculture,such as the cultivation of cottonwood or other species. The water could also simply be spread by overland flow through unmanaged forest stands to achieve improved water quality. Much of the water used in such ways will be lost by evapotranspiration. That which remains, however, could be used for other purposes.

Aquaculture might be an appropriate undertaking in the buffer zone,using waters from that zone and runoff waters which have been appropriately purified by means such as the above. In Louisiana, notable success has been achieved in aquaculture of blue catfish and crawfish. The latter can be cultured with trees standing within the culture enclosure, and suitable hydroperiod regulation might be of benefit to both. Another reason for encouraging aquaculture is that it may be possible through this means to increase the storage capacity for runoff water on the buffer zone lands. This could lessen the flooding problems on lower-lying lands to some extent.

Other techniques that may be appropriate for use in this buffer zone are schemes such as that proposed by Wolverton[178] to use water hyacinth for wastewater regeneration. In a treatment system of this kind, certain fertilizer elements escaping from agricultural lands may be partially recovered and re-applied to the fields near the treatment area. Methane gas and fertilizer can be recovered as by-products through fermentation of the hyacinth under anaerobic conditions, and possibly other by-products could be developed. This kind of system could potentially be a significant contribution to local energy needs and, more importantly, may improve the efficiency of energy use in agriculture.

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[178] Webre, 1975, op. cit.

It is not expected that uses for water regeneration or aquaculture would occupy much of the buffer zone land. A larger part of this zone might be managed for silviculture of single species or mixed stands of various trees under varying schemes of management and water-level regulation. Since the zone lies proximal to the developed lands, it will be easily accessible for harvest and maintenance operations. The largest part of the zone might be left to natural development or protective use. It would be desirable for a certain area of this zone to be set aside for experimental use in order to test varying strategies for management appropriate in this zone.

Exploitative Use Zone

The management of agricultural lands is an area of great uncertainty since future trends are largely dependent on future national, and even international, policy decisions. Projections can be found for a decline in land needed for farming nationally[179] as well as for an increase in agriculture in the Lower Mississippi River region.[180] Future trends will be also dependent on technological innovation. Especially important are those innovations that may offer hope of agricultural land use techniques that are not environmentally degrading and are more efficient, lowering the demand for land.

It seems likely that efficiency of agricultural land use can be further increased by more intensive cultivation and diversification of crops. Most cropland presently in the area is in sugar cane, which has been favored until recently by import quotas which make this practice competitive with higher-yielding, tropical sugar-producing areas.

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[179] E. O. Heady, et. al., *Agricultural and Water Policies and the Environment* (Iowa State University; Center for Agricultural and Rural Development, 1972), Report 40-T.

[180] National Academy of Sciences, *Productive Agriculture and a Quality Environment* (Washington, D. C.; National Academy of Sciences, 1974) 189p.

By-product recovery from sugar refining has been mainly molasses and bagasse conversion to paper or fiberboard. Small amounts of sugarcane wax are also recovered in Louisiana as well as thermoplastic and thermosetting resins. Activated carbon, furfural, and alpha-cellulose are potentially recoverable as by-products. Other opportunities exist, such as the utilization of both molasses and bagasse in the production of animal feeds by using these individually or in combination as substrates for production of single cell protein through culture of yeasts, bacteria, or fungi. Such protein may also be used eventually for human consumption. With such schemes, feed lots might become an appropriate agricultural land use associated with sugar refineries. Manures from the feed lots could then be used for production of methane gas and fertilizer, with optimum results perhaps obtained by blending with cellulosic material, such as water hyacinth grown in a water purification system as proposed by Wolverton.[181] In this way, waste from refining as well as cultivation could be much reduced, and intensification and diversification of agricultural land use can be simultaneously accomplished.

Aquaculture should be more seriously considered as a productive use of lands in agriculture, particularly those low-lying areas of the natural levee flanks where drainage is more difficult. Not only should accepted practices such as culture of catfish or crawfish be employed, but more innovative culture, such as algae production, should be considered at least experimentally. Besides its productive potential, aquaculture offers the potential of increasing the storage of rainfall and runoff on the agricultural lands.

Other means of increasing the storage of rainfall and runoff on agricultural lands should be actively investigated. Drainage canals might be made deeper than needed to convey ordinary runoff and have outlet controls so that a larger fraction of such waters could be held in static storage rather than dumped into adjacent basins. Such waters might be used in irrigation during dry periods.

Future growth of human settlement should be in such a way that less land will be required with less extensive proliferation of such accessory developments as roads, water lines, sewer lines, power lines, and so forth. In urban areas, such densification is already evident in increased numbers of apartment facilities. Single-family dwellings also might be arranged in cluster-form in ways that minimize land requirements and needless duplication of services.

Industrial land use should undergo similar densification through better layout and design of facilities and clustering. Certain features such as air or water pollution abatement facilities might be jointly operated and shared by a cluster of industrial users, with potential saving of space or improved efficiency of other resource uses.

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[181] Webre, 1975, op. cit.

Surface Water Management

Having defined the distribution of proposed land uses on the basis of constraints and opportunities set by both the natural environment and present uses, we may now proceed with definition of a proposed water management plan. The plan is based on integral consideration of use and water management requirements of the socio-economic complex and the forest, fish, and wildlife resources as discussed in previous chapters.

Flood Control and Protection

First, flood control should be considered as dictated by designation of the central Atchafalaya Basin for that purpose and by regional stresses related to inadequacy of the present floodway. To provide for immediate increase in flood-carrying capacity, the plan proposes enlargement of the Main Channel from mile 55 to Wax Lake Outlet through dredging to a bankfull cross-sectional area of approximately 6500 m^2 (70,000 ft^2), or 7500 m^2 (80,000 ft^2) when stated in terms of area below project flow line. These dimensions are suggested by the previous analysis of most probable dynamic equilibrium conditions and are believed to closely approximate a channel dimension that will be stable and self-maintaining under the prevailing Atchafalaya River regime if flow is partially confined by artificial levees. Exceedence of these dimensions is believed to result in a need for excessive maintenance dredging and associated spoil disposal unless flow is totally confined for all possible discharges below project flood magnitude through extension of such artificial levees as are present above mile 55.

A reduction from the 9200 m^2 (100,000 ft^2) dimension, as proposed by the U. S. Army Corps of Engineers, to 7500 m^2 (80,000 ft^2), as proposed here, should be obtained by limiting the width to which the channel will be dredged. It is believed that in view of conditions of prevailing discharges and sediment load, channel width should be in the order of 410 m (1350 ft) to prevent creation of an "underfit" stream channel with resulting development of lateral channel bars. Channel flows should be confined to the largest extent possible, with diversion during normal years occurring only insofar as required for maintenance of fish and wildlife resources. First, this will fulfill the requirement for minimizing sedimentation in overbank habitat. Secondly, this will insure to the greatest extent possible full utilization of river energy in channel maintenance and further enlargement if the self-maintaining cross-sectional area proves to have been under-estimated.

[illegible] of habitat.

Secondly, [illegible] of all diversion through distributaries [illegible] to fish [illegible] and as shown [illegible] proposed at the [illegible] the East Freshwater [illegible] is recommended for the [illegible] Diversion control with in- [illegible] navigation is proposed for the East and [illegible] will be further discussed [illegible] in fish and wildlife management strategies.

An additional complex of recommendations concerns the conveyance of floodwater from the floodway, across the Teche ridge, toward the Gulf of Mexico. The plan (Figure 9-2) proposes three main features which relate equally to flood control, flood protection, and navigation requirements. They are:

1) Transformation of Wax Lake Outlet to the principal continuant route for all discharges from the floodway;

2) control over diversion of Main Channel flows past Morgan City into the Lower Atchafalaya River; and

3) construction of a third, controlled outlet connecting the western floodway with West Cote Blanche Bay.

At present, the apex of the Atchafalaya Delta may, in a sense, be placed at the diversion of Wax Lake Outlet and the Main Channel through Six Mile Lake, with each channel representing a major distributary. Inability of stream flows under the prevailing Atchafalaya River regime to maintain the two channels at sufficient capacity was discussed earlier. Confinement of non-flood flows to a single channel until reaching Atchafalaya Bay is believed to serve greatly the objective of maintaining adequate capacity, maximizing at the same time utilization of river energy.

For several reasons Wax Lake Outlet has been selected as the continuant Main Channel rather than the Lower Atchafalaya River. The first reason relates to flood protection for the Morgan City area and the Verret Basin. A decrease in high-water stages of the Lower Atchafalaya River is required as a direct measure for protection of Morgan City proper and as an indirect measure to ameliorate backwater flooding of the Verret Basin and the Bayou Black levee ridges. The

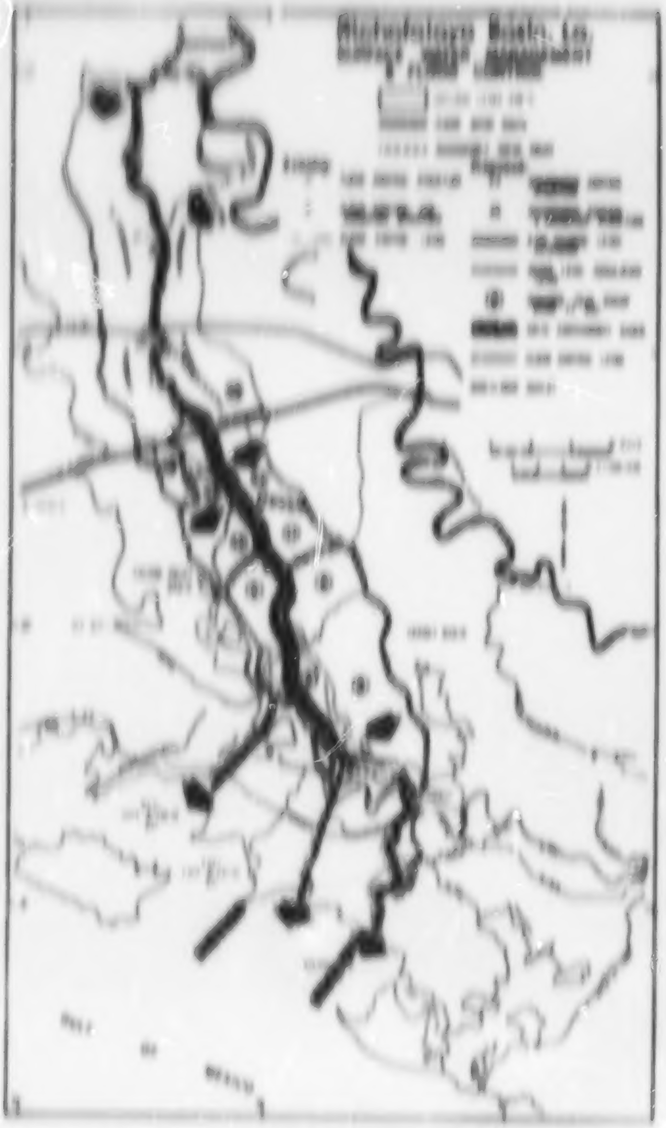

Figure 9-2. Proposed management of surface water for multiple and compatible use of the Atchafalaya Basin resources.

second reason concerns the earlier-stated requirement to separate deep-water access to Morgan City from the effects of delta building. Thirdly, present trends are toward natural enlargement of Wax Lake Outlet as a result of gradient advantages.

Associated with the flow routing through Wax Lake Outlet as the principal outlet, a control structure is proposed at the diversion of Wax Lake Outlet and the channel through Six Mile Lake leading toward the Lower Atchafalaya River. The principal objective of this structure, hereafter referred to as the Six Mile Lake structure, is to restrict flow diversion into the Lower Atchafalaya River and to prevent a dramatic reduction of its cross-sectional area through sedimentation. Yet, it is anticipated that some diversion will be necessary to provide partial abatement of salt water intrusion when drainage from the East Floodway and the Verret Basin are at a minimum.

The Six Mile Lake control structure would affect present Main Channel navigation to and from Morgan City, but an alternative route is available through the Intracoastal Waterway, which connects Morgan City with the Wax Lake Outlet. The proposed provision for navigation through the control structure, as indicated in Figure 9-2, is therefore an alternative to rerouting of lower Main Channel navigation to the Intracoastal Waterway.

Arising from the proposed partial separation of the West and East Floodway from the Main Channel for water management purposes, and with present outlet capacity being insufficient, a controlled and leveed additional outlet in the form of a spillway and/or channel is proposed. This outlet would serve the floodway west of the Main Channel for normal drainage as well as flood-routing to the Gulf. As indicated in Figure 9-2, the outlet, hereafter referred to as the Charenton Outlet, would parallel the present Charenton Canal and cross Bayou Teche. Flow from the floodway into the outlet would be regulated by a control structure to prevent excessive drainage of the West Floodway during normal years. To prevent backwater flooding of the Fausse Point Basin during outlet use for flood routing, separation of the proposed Charenton Outlet from the Charenton Canal and Bayou Teche is essential. A controlled connection with the Charenton Canal is proposed, however, to provide for additional drainage of the Fausse Point Basin during periods of excessive runoff.

With regard to flood control and flood protection, the plan is summarized schematically in Figure 9-3A for a condition of project flood use. Water diverted from the Mississippi River through the Old River control structure and Morganza Spillway and additional discharge from the Red River routed into the Atchafalaya Basin Floodway conform to present conditions. Within the floodway, exchange of water between the Main Channel and the adjacent East and West Floodways remains

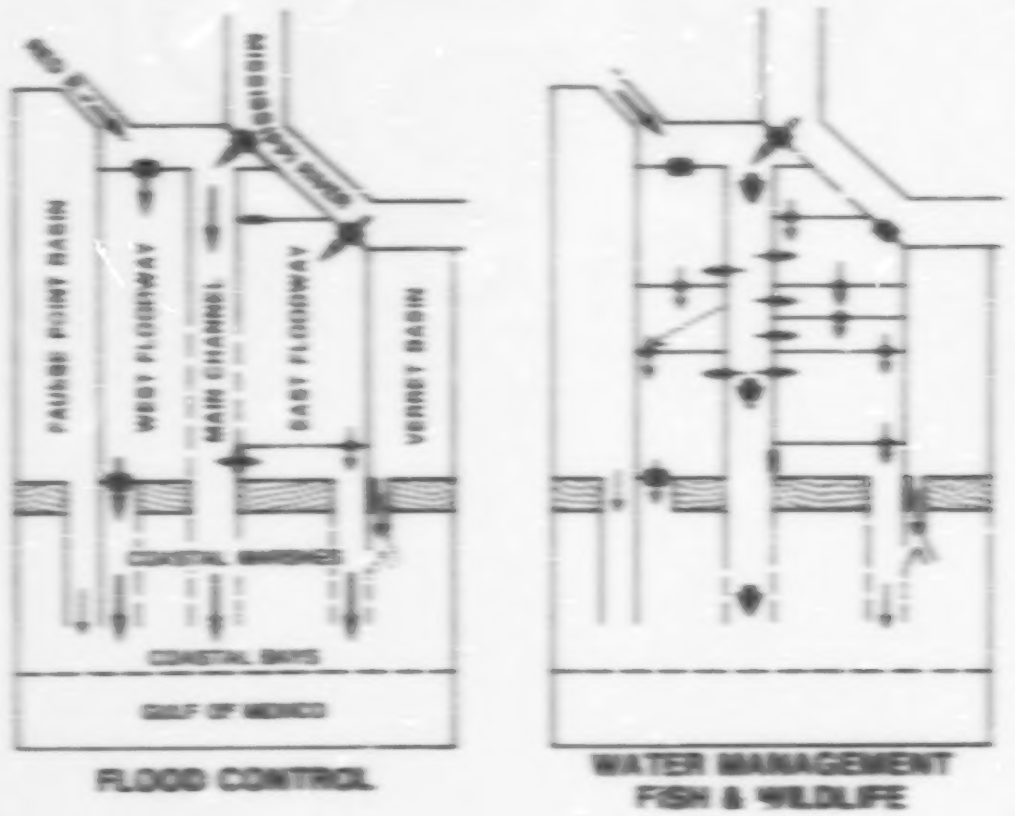
MISSISSIPPI RIVER
FAUSSE POINT BASIN
WEST FLOODWAY
MAIN CHANNEL
EAST FLOODWAY
VERRET BASIN
COASTAL MARSHES
COASTAL BAYS
GULF OF MEXICO
FLOOD CONTROL
WATER MANAGEMENT
FISH & WILDLIFE

Figure 9-1. Schematic summary of water management plan. Diagram A shows operation for project flood conditions; Diagram B shows operation during "normal" years for environmental management. Structures primarily for flood control are shown as rectangles, structures for environmental management as stars.

possible across the elevated banks below mile 55. Additional exchange would be possible if needed through the proposed Six Mile Lake structure.

Discharge from the leveed floodway across the Teche ridge is through three outlets, with Wax Lake Outlet the principal channel. The second uncontrolled outlet is the Lower Atchafalaya River, which would convey part or all of the East Floodway discharge. A third, controlled outlet serves the West Floodway. Outlet capacities cannot be specified here since necessary research would go far beyond the scope of the present study. However, as a tentative approximation, capacities of 21,250, 14,000 and 7,000 cms (750,000, 500,000 and 250,000 cfs) are envisioned for Wax Lake Outlet, the Lower Atchafalaya River, and Charenton Outlet, respectively.

Management of the Fluvial Swamps

For management of the fluvial swamps within the floodway, the plan recognizes three first-order hydrologic units: the Main Channel, the West Floodway, and the East Floodway. To achieve reduction in sedimentation, sufficient annual dewatering, and improvement of water quality, these three units are to become separate hydrologic entities to the extent that during normal flood years, water diversion from the Main Channel into the East and West Floodways is controllable, and dewatering of both floodway segments can occur independently of Main Channel stages. Separation of the Main Channel from the East and West Floodways would be achieved through the channel containment as proposed for flood-control purposes in the previous section, with necessary water diversion from the Main Channel taking place through a number of control structures. Locations of these structures are to be coincident with present and potential diversion channels and dictated by individual second-order management units, as will be discussed further.

Outflow from the West and East Floodway is to be controlled as well. The flood-control measures proposed in the previous section allow dewatering independently of Main Channel stage, together with control over the time and volume of outflow. Both would be achieved by use of the controlled Charenton Outlet as the drainage channel for the West Floodway. Outflow control with regard to the East Floodway requires additional measures. While drainage of the East Floodway under the plan proposed so far would be through the Lower Atchafalaya River and virtually independent of Main Channel stages as a result of the proposed Six Mile Lake control structure, no control over time and volume, and consequently over water level, is yet obtained. For that purpose, it is proposed that an embankment be constructed along the northern side of Six Mile Lake connecting the Main Channel levee with the East Floodway Protection Levee and containing a control structure with provision for navigation at the entrance to the alternate route of the Intracoastal Waterway.

The proposed measures as discussed above essentially provide two major basins with controlled input and output of river water and sediment and, therefore, controlled water level and water movement. Within each of these two basins, however, there are diverse requirements as to absolute water levels related to characteristics of the various management units. Obviously, a major difference in required absolute water levels is inherent to the general southward slope of the basin floor. Therefore, each of the two first-order basins is divided into a series of second-order hydrologic units. Depending on water-level requirements, these units are coincident with or combine individual management units defined earlier in the report (Figure 2-3). To achieve the stated water-management objectives, these second-order hydrologic units or sub-basins also require control over inflow and outflow.

Prior to detailing control at the management-unit level, the plan can be schematically summarized as in Figure 9-3B. The diagram shows the East and West Floodways as first-order hydrologic units, each containing a series of second-order units. At the lower end of both the East and West Floodways, a structure and continuant channel provide for controlled outflow. A number of structures allow controlled inflow from the Main Channel. As indicated by the solid lines, second-order units are physically separated from each other by water-level regulation levees that allow a certain maximum stage to be attained within each unit. Inflow into individual second-order units may be directly from the Main Channel and/or indirectly after routing through an adjacent unit to the north in which required stages are always higher. Control structures regulate outflow from each unit; the outflow is received by the units to the south in a cumulative process until discharged from the first-order drainage structure.

Management at Unit Level

In reference to Figure 9-2, management at the unit level may now be discussed with regard to minimum diversion requirements and flow-routing. The map shows actual second-order hydrologic units within both the East and West Floodways. The hydrologic units combine those management units having identical requirements as to minimum required water level during flood stage, as indicated by the circled values (peak swamp-stage). In the West Floodway, the Cocodrie Swamp and Beau Bayou Management Units are combined, as are the West Atchafalaya Floodway and Bayou Fordoche Management Units (Figure 2-3). In the East Floodway, the most northern hydrologic unit combines the Morganza Floodway and Alabama Bayou Management Unit and the Bayou des Glaises Management Unit above Interstate Highway 10. The most southern hydrologic unit combines the Crevasse, Upper Belle River, and Flat Lake Management Units, which all require a peak swamp-stage of 2.4 m (8 ft) MSL.

As proposed, management of each hydrologic unit is achieved in first instance through control over the flow directed into the major channels bounding each unit. This is opposed to control over the exchange between water-supplying channels and individual sub-basins, which would greatly hamper boat access to these sub-basins. Whereas water supply thus would be controlled, the movement of water into the swamp basins from adjacent channels, except the Main Channel, would retain its present characteristics if no further measures were taken to modify channel banks.

Following are the specific measures proposed with regard to water supply and drainage for water management at the unit level. First, the units within the West Floodway are discussed from north to south. With regard to monthly water levels, proposed hydrographs are those presented in the preceding part of this report dealing with the unit topography and hydrographs (Chapter VII).

In the West Floodway, inflow for all units to the north of the West Access Channel would be served by the Atchafalaya River, thus requiring a first-order control structure at the diversion of this river from the Main Channel. Channel size is judged sufficient to supply all necessary water so that the West Fresh Water Diversion Channel may be closed. Annual flooding of the Bayou Fordoche Management Unit (Henderson Lake area) to a maximum of 4.8 m (16 ft) MSL would occur through backwater flooding as presently occurs through Bayou La Rose and the West Atchafalaya Basin borrow pit. Since flooding of the Cocodrie Swamp and Beau Bayou Units is only needed to a stage of 12 feet, a water regulation levee with an elevation of 4.8 m (16 ft) MSL would be required along the southern side of Bayou La Rose, connecting the West Guide Levee and the high natural levee of Little Atchafalaya River. A second-order control structure across Little Atchafalaya River would provide for dewatering of the Bayou Fordoche Unit as well as water input for the Cocodrie Swamp and Beau Bayou Management Units. Commensurate requirements are closure of Upper Grand River and Butte La Rose Cutoff.

A minimum peak swamp-stage of 3.6 m (12 ft) MSL is required in common for the Cocodrie Swamp and Beau Bayou Units. This would demand a water-level regulation levee the same elevation as that along the northern side of the West Access Channel. The present spoil bank already attains or exceeds the 12-foot elevation. With water inflow regulated at the proposed Little Atchafalaya River structure, a dewatering control structure is required at the junction of the West Access Regulation Levee and the West Guide Levee. Alternatively, the structure may be placed in Lower Grand Bayou or Lake Fausse Point

Cutoff, with closure of the other channel. If deemed desirable, backwater flooding may be provided through the latter structure preceding additional inflow from the Little Atchafalaya River structure.

The Buffalo Cove Management Unit requires a minimum peak swamp-stage of 2.7 m (9 ft) MSL. Proposed water input is through the West Access Channel by means of a control structure at its diversion from the Main Channel. Dewatering would be served by the Charenton Outlet.

In the East Floodway, a similar strategy of flow routing is followed. Beginning with the most northern unit, Bayou des Glaises, a water-level regulation levee parallel to Interstate 10 is necessary since required water levels to the north of Interstate 10 exceed those to the south by .06 m (2 ft). To provide for annual flooding to 4.8 m (16 ft) MSL of the northern Bayou des Glaises Unit, there are two alternatives. The first is through the presently planned Alabama Bayou structure near Krotz Springs. The second is through backwater flooding from the Interstate 10 construction canal. In the first case, as shown in Figure 9-2, the regulation levee is to be placed north of the Interstate 10 canal, utilizing either abandoned railroad embankment or the canal spoil deposits. The levee should have a crest elevation of 4.8 m (16 ft) and contain a dewatering control structure across Bayou des Glaises.

If backwater flooding is determined to be more desirable, inflow for both the northern and the southern parts of the Bayou des Glaises Unit can be served at once by a control structure at the presently closed intersection of the Interstate 10 construction canal and the Main Channel. The water-regulation levee should then be placed to the south of Interstate 10 and contain a control structure across the canal leading from the Interstate 10 construction canal southward to the East Freshwater Distribution Channel.

The plan provides for flooding of the southern Bayou des Glaises Unit to 4.2 m (14 ft) MSL through a proposed control structure at the junction of the Interstate 10 canal and the Main Channel as referred to above. A water-level regulation levee is required along the northern bank of the East Freshwater Diversion Channel, with a crest elevation of 4.2 m (14 ft) and containing a second-order control structure to regulate dewatering. As proposed, the structure is located at the junction of the canal leading northward to Interstate 10 and the East Freshwater Distribution Channel.

In the Bayou Pigeon Unit, the management requirement is for annual flooding to a stage of 3.3 m (11 ft) MSL. It is proposed that water be supplied through the East Freshwater Diversion Channel as occurs at present, with diversion from the Main Channel regulated by a control structure. Adjacent units to the south require a peak swamp stage of only 2.4 m (8 ft) MSL. A water-regulation levee is necessary along the southern margin of the Bayou Pigeon Unit; that is, along the East Access

Channel so that existing spoil deposits can be utilized. The embankment should contain a second-order structure, which would be located at the East Guide Levee borrow-pit, for dewatering.

The hydrologic entity composed of Upper Belle River, the Crevasse, and Flat Lake Management Units has an annual flood-stage requirement of 2.4 m (8 ft) MSL. As at present, water would be supplied by the West Access Channel, but with a provision for inflow control by means of a structure. The proposed embankment along the northern side of Six Mile Lake and the associated structure at the Intracoastal Waterway that were discussed earlier would serve stage regulation and dewatering, respectively.

Inherent to the proposed structural measures is a constraint on navigation. Navigation locks proposed at the East and West Access Channels and at the Intracoastal Waterway provide for cross-basin navigation and unrestricted access to the East and West Floodways south of the access channels. However, proposed secondary water-management structures would prevent navigation from crossing boundaries of the four hydrologic units to the north. This does not necessarily cause a major conflict with regard to small-boat traffic related to commercial and sports fisheries since boat ramps presently provide for access to each of these units. Larger craft, such as associated with the mineral industry, must, however, be taken into consideration. Whereas further evaluation of this problem is necessary in regard to precise requirements, possible solutions other than a multitude of navigation locks are available. Boats and barges required for maintenance of oil fields may be stationed permanently within hydrologic units. Since roads provide access to the guide levees, construction of dock facilities could provide for transfer of heavy equipment onto barges. Earthen dams may be constructed adjacent to secondary water-management structures and be temporarily removed to allow passage of drilling rigs, which is an infrequent event.

So far, the questions of water movement from the supply channels into adjacent swamp basins and that of volume of water to be diverted to fulfill requirements of individual management units have been tacitly ignored. Previous studies identified various circulatory conditions leading to insufficient water circulation and water quality problems.[182, 183] From this, it appears a throughflow regime or a combination of head and backwater flooding are the regimes most desirable; that is, where annual flooding provides for water input across the upper margin of a basin, forcing water to move through the swamp as a result of the general north-to-south gradient. This is opposed to a

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[182] Coastal Environments, Inc., 1974a, *op. cit.*

[183] Coastal Environments, Inc., 1974b, *op. cit.*

condition where water enters predominantly from the side and lower end, resulting in stagnation and insufficient annual replacement of water in the upper and central parts of the basin.

In accordance with the above point of view, the proposed plan renders the possibility to provide maximum circulation for a given volume of water input. With one exception, water is supplied at the upper end of the units, and drainage is across the lower margin. Additional measures should be taken, however, to ensure water input across the upper margin of individual units.

In several instances, the supply channel banks forming the upper margin of individual units are nearly continuous and elevated by spoil deposits. Where this is the case, provisions should be made to allow inflow across these banks in a manner resembling natural overbank flooding as much as possible. Preferably, this may be accomplished by the construction of wide, shallow gaps. In some cases, as in Buffalo Cove, use may be made of existing mineral industry canals as a water distribution system along the upper margin of the unit.[184]

The mentioned exception to the proposed throughflow regime concerns the Bayou Fordoche Unit. Here, the present backwater flooding regime is retained since the unit is bounded on the north by the large watershed of the West Atchafalaya Floodway. Thus, local runoff may provide sufficient water input across the upper margin and a flushing effect to offset the disadvantage of lesser circulation associated with a backwater regime.

An additional reason for supplying water to the upper end of each unit relates to river gradient. It ensures maximum availability of water during low-river stages, in either low-discharge years or during summer months, for reasons of forcing water circulation through the swamp. The latter may be a desirable management strategy which becomes available if drainage is independent of Main Channel stage as proposed. Simultaneous operation of inlet and outlet structures can be used to produce a limited flushing of both the East and West Floodway systems.

The question of volume of water to be diverted to fulfill requirements of individual management units may be addressed using Figure 9-4. The diagram is a schematic representation of the floodway management units. Units are identified as follows:

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[184] *Ibid.*

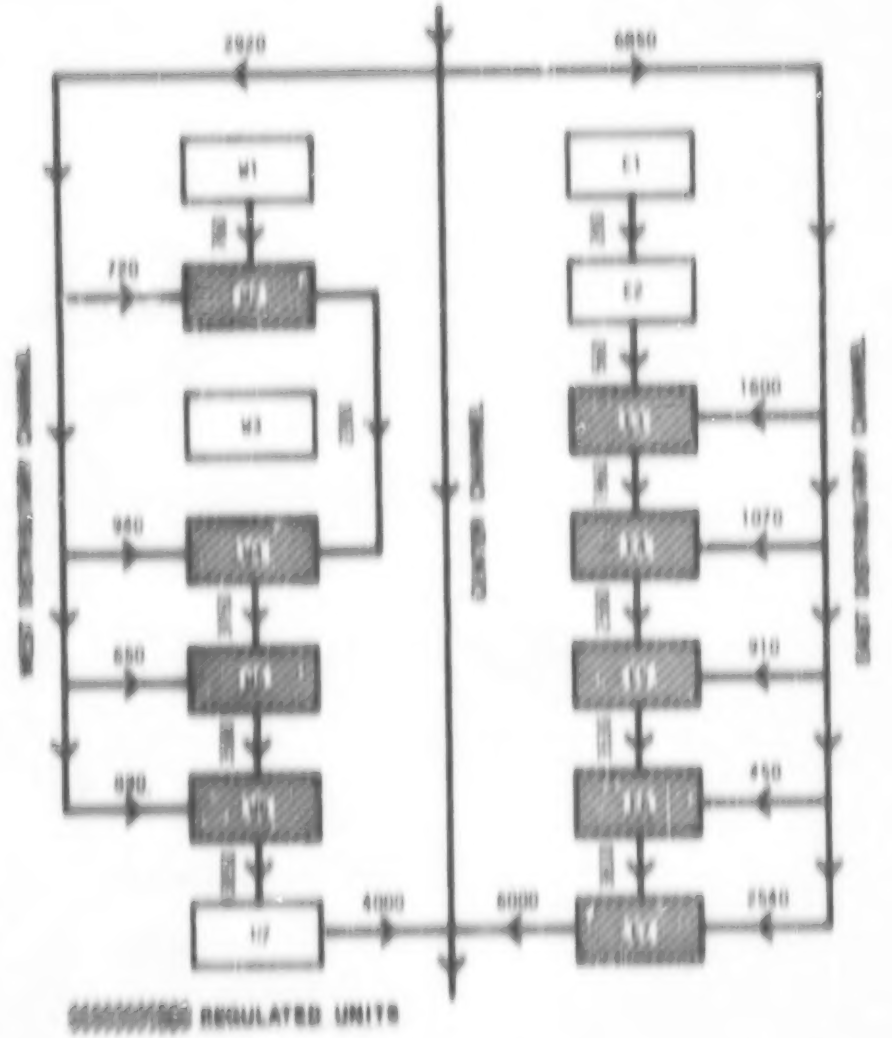
2920
6850
W1
E1
720
E2
1600
W3
940
1070
650
910
620
450
W7
4000
6000
2540
REGULATED UNITS

Figure 9-4. Schematic representation of floodway management units and water routing. Values represent highest monthly discharge for minimum water requirements.

West Floodway Units	East Floodway Units
W1 West Atchafalaya Floodway	E1 Morganza Floodway
W2 Bayou Fordoche	E2 Alabama Bayou
W3 Warner Lake	E3 Bayou des Glaises
W4 Cocodrie Swamp	E4 Pigeon Bay
W5 Beau Bayou	E5 Flat Lake
W6 Buffalo Cove	E6 Crevasse
W7 Six Mile Lake	E7 Upper Belle River

Each unit is considered as an entity with a respective point of inflow and outflow. It is further assumed that full control is exercised over the entire range of discharges at all inlet and outlet structures and that excess water is discharged into the next lower unit. Within the above framework and utilizing storage characteristics of each unit, one can determine on a monthly basis river-water supplements required to attain given target stages within each unit. Target stages used here are the average monthly stages for the period of record of 1960 through 1970.

Utilizing the water-resources data and methods described in previous chapters, water budgets were developed for each management unit for average conditions and for a monthly time unit. Tables 9-1 and 9-2 show the results for the West and East Floodways, respectively. For each unit in the tables, the following values are listed:

Target Stage	(TS)	Target mean water level of management unit in feet;
Storage Required	(SR)	Volume of water in storage below target stage in million cubic feet (mcf);
Upstream Flow	(UF)	Input from upstream management unit in mcf;
Local Yield	(LY)	Input from runoff within unit in mcf;
Total Inflow	(TI)	Sum of upstream flow and local yield in mcf;
Excess	(EX)	Water in excess of storage requirement in mcf;
Deficiency	(DE)	Supplemental water required to satisfy storage requirement in mcf.

Table 9-1. Water Budget, Regulated Management Units, West Atchafalaya Floodway.

[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	10.9	4600	86	−31	55		145
November	11.1	4800	408	396	804	606	
December	12.9	8000	1365	984	2349		851
January	15.1	13100	2026	1148	3174		1926
February	15.7	14600	1863	1163	3026	1326	
March	16.5	16400	1333	749	2082	282	
April	17.1	16700	950	246	1196		1104
May	17.5	19000	742	−63	679	379	
June	15.6	14300	167	−577	−410	4290	
July	12.9	8100	106	−198	−92	6108	
August	12.2	6500	0	−380	−380	1226	
September	10.8	4400	4	−283	−279	1921	
Total			9050	3154	12204	16230	4026

[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	6.2	600		62	62		138
November	6.0	500	606	121	727	827	
December	8.1	1200		423	423		277
January	10.4	2200		478	478		522
February	11.2	2700	1526	502	2028	1528	
March	13.4	4400	282	326	608		1092
April	14.7	6900		67	67		2433
May	15.2	6300	379	−104	275	875	
June	12.2	3400	4290	−182	4108	7008	
July	8.7	1400	6108	60	6168	8168	
August	7.0	900	1220	−16	1204	1804	
September	5.6	400	1921	−29	1892	2292	
Total			16230	1710	18040	22592	4462

Table 9-1. (continued). Water Budget, Regulated Management Units, West Atchafalaya Floodway.

BEAU BAYOU

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	5.0	200		35	35		65
November	4.6	200	827	62	889	889	
December	6.7	600		236	236		266
January	8.5	1100		266	266		235
February	9.3	1400	1528	282	1810	1510	
March	11.8	2700		180	180		1130
April	14.4	4400		27	27		1673
May	13.6	3900	875	-75	800	1300	
June	10.6	2100	7000	-122	6086	8605	
July	7.1	700	8140	23	8191	9581	
August	5.3	200	1804	1	1805	2305	
September	4.2	100	1792	-3	2289	2389	
Total			22592	912	23624	26670	3256

BUFFALO COVE

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	4.0	300		102	102	2	
November	3.7	300	809	190	1680	1085	
December	5.0	100		762	762	962	
January	6.4	600		699	699	298	
February	6.8	900	1510	730	2240	1940	
March	8.7	1900		399	399		401
April	10.7	4000		-228	-228		2309
May	10.3	3300	1300	-717	583	1283	
June	8.0	1400	8686	-903	7783	9683	
July	5.4	400	9581	-267	9314	10324	
August	4.2	300	2305	-202	2103	2203	
September	3.5	200	2389	-173	2216	2316	
Total			26670	413	27083	29982	2909

Table 9-1. Water Budget, Regulated Management Units, East Atchafalaya Floodway.

BAYOU DES GLAISES

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	4.8	200	56	50	106	6	
November	4.0	100	401	167	568	668	
December	6.0	400	1163	582	1745	1445	
January	7.9	1000	1602	815	2417	1817	
February	8.7	1500	1554	868	2421	1922	
March	11.5	4400	1086	618	1704		1196
April	14.4	9400	680	172	852		4148
May	13.5	7700	487	-83	424	2124	
June	10.8	3500	21	-343	-322	3878	
July	6.8	600	122	58	180	3080	
August	5.0	200		30	30	430	
September	4.0	100		18	18	118	
Total			7182	2952	10134	15478	5344

PIGEON BAY

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	4.4	200	6	125	131	31	
November	4.0	100	668	105	773	873	
December	5.8	700	1445	465	1910	1310	
January	7.4	1600	1817	242	2059	1159	
February	8.1	2100	1922	471	2393	1893	
March	10.4	4400		292	292		2000
April	12.6	7200		20	20		2780
May	11.8	6300	2124	-192	1932	2832	
June	9.4	3300	3878	-198	3680	6680	
July	6.2	900	3080	115	3195	5595	
August	4.7	300	430	40	470	1070	
September	3.8	100	118	4	122	322	
Total			15478	1499	16977	21765	4780

Table 9-2. (continued). Water Budget, Regulated Management Units, East Atchafalaya Floodway.

FLAT LAKE

	TS	SR	UF	LF	IL	ER	DE
October	3.2	1100	31	-46	-15		
November	2.8	800	873	308	1181	1481	335
December	3.9	2060	1310	679	1989	789	
January	5.0	3600	1159	577	1736	136	
February	5.4	4200	1893	650	2543	1943	
March	7.1	7100		441	441		2439
April	8.8	10200		133	133		
May	8.3	9300	2832	-142	2690	3590	
June	6.5	6500	6680	-437	6243	9043	
July	4.3	2500	5595	-150	5445	9445	
August	3.3	1200	1070	-231	839	2139	
September	2.8	800	322	-6	316	716	
Total			21765	1776	23541	29282	574

THE CHEVASSE

	TS	SR	UF	LF	IL	ER	DE
October	2.0	873		7	7	7	
November	1.8	700	1481	180	1661	1761	
December	2.2	900	789	439	1228	1028	
January	2.8	1200	136	570	706	476	
February	3.2	1500	1943	525	2468	2168	
March	4.2	2200		377	377		377
April	5.5	3650		224	224		1174
May	5.2	3300	3590	91	3681	4781	
June	4.1	2100	9043	-144	8899	9499	
July	2.8	1200	9445	-97	9348	10248	
August	2.2	900	2139	-131	2008	2308	
September	2.0	800	716	-74	642	742	
Total			29282	1967	31249	32749	1549

Table 9-2. (continued). Water Budget, Regulated Management Units, East Atchafalaya Floodway.

UPPER BELLE RIVER

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	2.0	2500	7	149	136	136	
November	1.8	2000	1761	749	2510	3010	
December	2.2	3100	1020	1796	2826	1726	
January	2.8	5500	406	1589	1995		405
February	3.2	7300	2168	1708	3876	2076	
March	4.2	12300		897	897		4203
April	5.5	19000		110	110		6590
May	5.2	17400	4081	-905	3176	4776	
June	4.1	11800	9999	-1453	8546	14246	
July	2.9	5500	10248	-492	9756	16056	
August	2.2	3100	2308	-642	1666	4066	
September	2.0	2500	742	-282	460	1060	
Total			32740	3221	35974	47072	11098

For each regulated unit, total inflow from an upstream unit and local rainfall in excess of the need for a particular month are released to the downstream unit. Water deficiency is satisfied by withdrawal from a water-supply channel. Under this scheme, maximum use is made of the fresh water developed from local rainfall. Some statistics of interest are generated from input of normal monthly water yield into the water management model. Tables 9-3 and 9-4 summarize supplemental and return-flow requirements, along with corresponding normal monthly flow volumes of the Atchafalaya River at Simmesport, Louisiana. It may be noted that the total flow requirement of the floodway swamps under this management plan is a negligible fraction of water normally available in the Main Channel. Consequently, discharge capacity requirements for each branch of the model are small. These requirements are shown in Figure 9-4 as developed by converting the maximum monthly volumes of excess and supplemental flows of Tables 9-3 and 9-4 into mean cubic feet per second.

It should be emphasized that a plan of operation and design should take into account additional factors. Target stages may need to be revised if more data become available on water-level requirements. Also, additional input of water may be necessary to force circulation during months when water-quality problems are likely to arise. Several refinements of analysis techniques could be employed in a more comprehensive study. The most important refinement is the inclusion of simulation trials conducted on the water-management model. Such trials should cover many years of meteorological data to ascertain how the system reacts during extremely wet and dry periods and enable adjustment of the parameters of the system to handle variations from normal conditions.

Management of the Coastal Area

While complexity of problems in the coastal area did not permit development of a comprehensive management strategy for that area, some specific recommendations can be made and are integrated into the proposed plan (Figure 9-2). These are for Wax Lake Outlet to become the principal extension of the Main Channel and for containment of delta growth associated with the discharge of water and sediment from the outlet.

With regard to flood protection and navigation for the Morgan City area, the reasons for making Wax Lake Outlet the principal channel were already stated. There is an additional reason when considering present diversion of river water and sediment into the Terrebonne marshes. Even though the benefit of such sedimentation as a measure to offset land loss is fully appreciated, it may be more desirable to offset land loss by new delta building than to attempt restoration of the marsh system in its present state. Under the proposed plan with

Table 9-1. Summary of Supplemental Flow Requirements, Million Cubic Feet.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						WEST [illegible]							
W2	145		811	2936			2294						4899
W4	138		277	532		1092	2433						4462
W5	65		166	236		1178	1673						3318
W6						661	2389						3050
Total	348		1292	3902		2913	7510						16023
						EAST [illegible]							
E3						2136	4149						[illegible]
E4						3089	2788						[illegible]
E5	835					2429	2967						[illegible]
E6						323	1176						1499
E7				485		4217	6596						[illegible]
Total	835			485		10889	17661						[illegible]
Grand Total	1183		1292	3987		13902	25179						[illegible]
[illegible] Flow, MCF	299	225	335	445	522	729	832	785	581	437	273	236	[illegible]
% Div.	0.57		0.39	0.69		1.77	1.08						0.78

Table 9-4. Summary of Return Flows, Million Cubic Feet.

	W. Pwy.	E. Pwy.	Total	Net Gain	Net Loss	% of Simmesport
October	2	156	158	-428	1025	-0.49
November	1080	3010	4090	4090		1.86
December	962	1726	2688	1396		0.42
January	199			-3795	2888	-0.65
February	1940	2076	4016	4016		9.77
March					12882	-1.77
April				-25238	25179	-3.06
May	1283	4776	6059	5274		0.67
June	9683	14146	23829	23248		4.00
July	10324	16056	26380	25943		5.94
August	2203	4066	6269	5996		2.20
September	2316	1060	3376	2882		1.40
TOTAL	29992	47072	77064	33423		0.60

reduced flows through the Atchafalaya River, a transition to more saline conditions would occur, and a gradual increase in the length of land-water interface in the marsh system would result through natural processes of subsidence and wave erosion. As experienced in other areas along the Louisiana coast, such as Barataria Bay, a highly productive brackish-to-saline estuarine environment can be expected to evolve.[185] Commensurate development of the delta in Atchafalaya Bay will produce a new freshwater environment adjusted to the variation in river discharges under which it develops. Such a process of commensurate gain and loss would be a replication of former natural processes along the Louisiana coastal zone prior to man's interference with the natural sequence of deltaic development and deterioration.

While a forced transition of the Terrebonne marshes to more saline conditions is viewed as a viable possibility, this would require additional measures in order to prevent rapid deterioration through saltwater intrusions. Commensurate with decreasing Lower Atchafalaya River discharges, provisions should be made to make full use of Verret Basin runoff as a source of fresh water for management of the salinity regime.

Management of delta growth through containment is proposed as a necessary measure to protect the Cote Blanche Bay system to the east and to fulfill navigation requirements. Under the proposed plan, sediment would be discharged primarily from the Wax Lake Outlet, and shallowness of Atchafalaya Bay must be expected to produce a broad delta front. Thus, even though the delta apex would be displaced westward, delta progradation would still block deep-water access to the Lower Atchafalaya River. For this reason, it is proposed that an embankment be constructed limiting eastward growth of the delta. Present spoil deposits along the Atchafalaya Bay navigation channel could be utilized, while additional material for the embankment could be obtained through dredging necessary to bring the navigation channel again to its authorized depth.

A second delta containment bank is proposed along the west side of the developing delta to protect the Cote Blanche Bay estuarine system from excessive sedimentation and infilling. Material for the western embankment could be derived from dredging necessary to enlarge the Wax Lake Outlet to proposed dimensions.

The plan for multi-use management of the Atchafalaya Basin as set forth here still leaves many questions unanswered. Complexity of problems in the coastal area did not allow specification of requirements sufficient for detailed plan-development. Equally, the paucity of topographic and other baseline data hampered development of detailed recommendations for the Fausse Point and Verret Basin. On the other hand, it must be pointed out that care was taken not to foreclose any identified options for management of both the coastal area and the basins adjacent to the floodway insofar as these options could be reconciled with the overriding requirements for flood control.

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[185] Gagliano *et al.*, 1973, *op. cit.*

For the Atchafalaya Basin Floodway, it is believed that the plan achieves many of the objectives of this study in that it provides for a means of flood control that minimizes environmental impact and guards long-term benefits of the Atchafalaya Basin for both exploitative and protective uses.

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APPENDIX A

Louisiana Mammals Whose Range Includes the Atchafalaya Basin

Opossums

Virginia opossum (*Didelphis virginiana*)

Shrews

Short-tailed shrew (*Blarina brevicauda*)
Least shrew (*Cryptotis parva*)

Bats

Southeastern myotis (*Myotis austroriparius*)
Eastern pipistrelle (*Pipistrellus subflavus*)
Big brown bat (*Eptesicus fuscus*)
Red bat (*Lasiurus borealis*)
Seminole bat (*Lasiurus seminolus*)
Hoary bat (*Lasiurus cinereus*)
Northern yellow bat (*Lasiurus intermedius*)
Evening bat (*Nycticeius humeralis*)
Rafinesque's big-eared bat (*Plecotus rafinesquii*)
Brazilian free-tailed bat (*Tadarida brasiliensis*)

Armadillos

Nine-banded armadillo (*Dasypus novemcinctus*)

Rabbits

Eastern cottontail (*Sylvilagus floridanus*)
Swamp rabbit (*Sylvilagus aquaticus*)

Rodents

Gray squirrel (*Sciurus carolinensis*)
Fox squirrel (*Sciurus niger*)
Southern flying squirrel (*Glaucomys volans*)
American beaver (*Castor canadensis*)
Marsh rice rat (*Oryzomys palustris*)
Eastern harvest mouse (*Reithrodontomys humulis*)
Fulvous harvest mouse (*Reithrodontomys fulvescens*)
White-footed mouse (*Peromyscus leucopus*)
Cotton mouse (*Peromyscus gossypinus*)
Hispid cotton rat (*Sigmodon hispidus*)
Eastern wood rat (*Neotoma floridana*)

Common muskrat (*Ondatra zibethicus*)
Roof rat (*Rattus rattus*)
Norway rat (*Rattus norvegicus*)
House mouse (*Mus musculus*)
Nutria (*Myocastor coypus*)

Carnivores

Coyote (*Canis latrans*)
Red fox (*Vulpes fulva*)
Gray fox (*Urocyon cinereoargenteus*)
Black bear (*Euarctos americanus*)
Northern raccoon (*Procyon lotor*)
Long-tailed weasel (*Mustela frenata*)
North American mink (*Mustela vison*)
Striped skunk (*Mephitis mephitis*)
Nearctic river otter (*Lutra canadensis*)
Bobcat (*Lynx rufus*)

Deer

White-tailed deer (*Odocoileus virginianus*)

APPENDIX B

Annotated List of Some Common and Rare Birds of the Atchafalaya Basin

Heronlike Birds

Herons and Egrets

These are common birds in swamp and marsh habitats, and usually several species may be seen on nearly every outing into the basin. Commonly observed species include the great (American) egret, snowy egret, Louisiana heron, little blue heron, and green heron. Less frequently seen are the great blue heron and the yellow-crowned night heron.

Storks

The wood stork is fairly common in the swamps of the basin during the summer, although it apparently does not nest there.

Ibises

The white ibis is common in the basin. It is most often observed flying overhead in flocks of 10 - 100 individuals in the early morning or late afternoon.

Herons, ibises, and wood storks feed mostly on small fishes, crustaceans (including crawfishes), frogs, snails, and aquatic insects. Terrestrial insects are also taken. The little blue heron particularly feeds heavily on crawfishes when they are abundant. Many little blue herons may be observed as they walk along hunting for crawfish at the edge of the borrow-pit canal inside the East Protection Levee in the spring. Examination of their droppings at this time reveals almost exclusive crawfish remains.

Ducks and Geese

See section of report on waterfowl.

Hawklike Birds

Turkey vultures and black vultures are common in the basin.

The red-shouldered hawk is perhaps the most common hawk in the basin and is a year-round resident in wooded areas. The broad-winged hawk is mostly a summer resident in wooded areas. The red-tailed hawk is most abundant in the winter in cleared areas. The marsh hawk occurs in agricultural fields and in marshes in the winter.

The Mississippi kite is abundant in the basin as a summer resident. The swallow-tailed kite also occurs here during the summer, but is rare.

The American kestrel (sparrow hawk) is a common winter resident in cleared areas of the basin.

Besides the above-mentioned birds, the following species are rare.

Osprey

The osprey is an uncommon or rare summer resident. A fish eater, it may be expected to occur in the Lake Verret and Grand Lake/Six Mile Lake area and near other large lakes in the basin.

Southern Bald Eagle

The bald eagle occurs in scattered areas in south Louisiana where it nests in the winter. A recently occupied bald eagle nest is approximately 25 miles southeast of Morgan City. Also a fish eater, this bird may be expected in the vicinity of large lakes. The southern bald eagle is currently listed as an endangered species.

Peregrine Falcon

The peregrine falcon is an endangered species which occurs in the marshes in the lower basin.

Fowl-Like Birds

Quail and Turkey

The bobwhite quail occurs throughout the basin except in the marshes. Quail exist in the swamp and bottomland hardwoods areas in low numbers. Barely huntable populations of quail occur in the cleared farmlands in the upper basin.

Wild turkeys may have originally occurred as a natural population in the higher forested areas of the basin. The present turkeys, however, have been introduced into Pointe Coupee and Iberville Parishes.

Crane-Like Birds

Rails

Clapper rails occur in the more saline marshes in the lower basin. The king rail prefers the fresher marshes, lake shores, and drainage ditches in wet fields. These birds are year-round residents. The Virginia rail, sora, and yellow rail occur in fresh marshes and wet, grassy fields and are winter residents.

Gallinules

Purple and common gallinules occur mostly in the summer. They inhabit the banks of bayous, ponds, and lakes in the swamps and marsh.

Coots

The coot, or poule d'eau as it is called in Louisiana, is abundant on lakes and ponds throughout the basin in the winter. A few coots remain in the basin in the summer. The coot is a popular game bird in south Louisiana.

Shore Birds

Plovers

Most of the plovers in Louisiana are found in the immediate coastal area on beaches and exposed tidal flats. The killdeer is an exception, and it is usually common the year around (abundant in winter) in inland cleared areas such as fields, golf courses, and levees. The golden plover is sometimes found in similar locations during migration in the spring.

Sandpipers

The most outstanding birds among this group in the basin are the game birds -- the American woodcock and the common snipe. The woodcock occurs most abundantly in the winter. It feeds at night in agricultural fields and cleared areas on earthworms or other ground-dwelling organisms and seeks cover during the day in forested areas. The Atchafalaya Basin is an important wintering area for large numbers of woodcock each year.

The common snipe is most often associated with the marsh, where it is most often hunted. Like the woodcock, the snipe is a winter resident and has similar food habits, although it often feeds in the daytime.

Besides the woodcock and snipe, the upland, spotted, and solitary sandpipers may be observed at inland localities near farmlands, while the willet, the pectoral sandpiper, and the least sandpiper are most often seen on marsh mudflats and beaches.

Gulls and Terns

These birds may occasionally be observed in inland areas, particularly near large rivers, but they are usually strictly coastal birds. Herring gulls and laughing gulls are common from Morgan City southward. The laughing gull is a year-round resident, while the herring gull is usually absent in the summer. The ring-billed gull is a common winter resident in the coastal area.

Six kinds of terns are fairly common on the coast. The Forster, royal, and Caspian terns are permanent residents; the black tern and the least tern are summer residents, while the gull-billed tern is present in the winter.

Skimmers

The black skimmer is a common coastal bird which frequents the Gulf beaches and islands in bays.

Pigeon-Like Birds

Besides the domestic pigeon, which is abundant in Morgan City, the mourning dove is the only species in this group which is common. It is a game species which occurs year-round in the basin, mostly in and near farmlands. Dove populations are greatly increased in the winter when large numbers of migrating doves come in from the north. Huntable numbers of doves occur in the winter in the farmlands in the northern end of the basin.

Owls

At least three species of owls are common in the basin: the great horned owl, the barred owl, and the screech owl. The barn owl is probably also common in the cleared areas to the north. Of the three common species, the barred owl is undoubtedly the most abundant. Owls occur throughout the wooded areas of the basin, and they may often be seen roosting in treetops during the daytime near Interstate 10 and U. S. Highway 190. Barred owls are frequently struck by cars and killed along the non-elevated portions of highways in and around the basin.

Owls are top carnivores, feeding mostly on small mammals. They also feed on insects, lizards, crawfishes, fishes, and small birds. The nocturnal hooting of owls is a characteristic sound in the Atchafalaya Basin swamp.

Kingfisher

The belted kingfisher is one of the most characteristic birds of the swamp and is familiar to most sportsmen and hunters. The kingfisher has a habit of flying ahead of a running boat in bayous, usually for a short distance, but often for a mile or two. It is also frequently seen perched on telephone wires along a roadside canal, waiting for a small fish to appear near the water surface. Small fishes make up the largest part of its diet, which also includes insects and small frogs. The kingfisher is a year-round resident in the swamps and marshes of the basin.

Woodpeckers

Six woodpeckers are found in the Atchafalaya Basin: the flicker, the red-bellied woodpecker, the pileated woodpecker, the hairy woodpecker, the downy woodpecker, and the yellow-bellied sapsucker. All of the woodpeckers, except the last-named species (which is present in the winter months), are permanent residents and are fairly common. The pileated woodpecker, due to its large size and striking appearance, is perhaps the species most frequently observed by the average sportsman in the basin. The pileated woodpecker resembles, in general body form and to some degree in coloration, the endangered (or extinct?) ivory-billed woodpecker, which could possibly occur in certain areas of the basin.[186] Indeed, the mature, climax live oak - mixed hardwood forests[187] in the vicinity of Cypress and Tiger Islands in the lower basin would appear to be excellent wildlife habitat in general and prime ivory-billed woodpecker habitat. Every effort should be made to preserve these forests, since they are an endangered habitat type in the south.[188]

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[186] David Nevin, "The Irresistible, Elusive Allure of the Ivory-bill," Smithsonian (Volume 4, No. 11, 1974).

[187] U. S. Department of the Interior, 1974, *op. cit.*, p. 77.

[188] Richard K. Yancey, "The Vanishing Delta Hardwoods: Their Wildlife Resources," (Presentation to the Governor's Seminar on the Mississippi Delta Hardwoods, Little Rock Arkansas, 1969).

Perching Birds

This large order is well-represented in the basin. Some of the more common and well-known species include the following.

Permanent Residents

Forested areas: blue jay, common crow, Carolina chickadee, brown thrasher, common yellow throat, red-winged blackbird, common grackle, cardinal.

Cleared areas, including towns: blue jay, common crow, mockingbird, brown thrasher, loggerhead shrike, starling, house sparrow, eastern meadowlark, red-winged blackbird, common grackle, brown-headed cowbird, cardinal.

Marshes: common crow, fish crow, long-billed marsh wren, loggerhead shrike, red-winged blackbird, eastern meadowlark, common grackle, boat-tailed grackle, seaside sparrow.

Summer Residents

Forested areas: Acadian flycatcher, wood thrush, white-eyed vireo, red-eyed vireo, prothonotary warbler (this is one of the most common birds in the swamp areas of the basin in the summer; it is well known to local residents as simply the "yellow bird"), Kentucky warbler, hooded warbler, orchard oriole, summer tanager, painted bunting (this highly colorful bird is also well known to local residents as the "pop," or "papa").

Cleared areas, including towns: eastern kingbird, purple martin, orchard oriole, Baltimore oriole, summer tanager.

Winter Residents

Forested areas: eastern phoebe, hermit thrush, ruby-crowned kinglet, cedar waxwing, yellow-rumped (Myrtle) warbler, rufous-sided towhee, white-throated sparrow, swamp sparrow.

Cleared areas, including towns: tree swallow, American robin, ruby-crowned kinglet, cedar waxwing, rusty blackbird, Brewer blackbird, rufous-sided towhee, white-throated sparrow.